

**Individual Differences in
Environmental Sensitivity
Implications for Psychological Wellbeing**



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St Cross College
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A thesis submitted for the degree of
Doctor of Philosophy
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Abstract

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Theories of *Environmental Sensitivity* predict that there is inter-individual variation in the degree of processing and responding to the surrounding environment, which can explain individual differences observed in psychological outcomes. *Sensory-Processing Sensitivity* (SPS) describes a personality trait, which is thought to reflect heightened environmental sensitivity (i.e., increased processing and responding to the environment). The evidence in this thesis supports this claim, as SPS was found to moderate the effect of life experiences on different psychological outcomes. High SPS reflected a risk factor for high levels of depression and low levels of wellbeing, which was related to increased responsivity to retrospective negative childhood experiences (in adults), as well as increased responsivity to concurrent negative life events (in adolescents). It also found that high SPS individuals showed attenuated responsivity to positive childhood experiences (in adults), although no moderation of positive life events was observed in adolescents. Together, these studies show that high SPS reflects heightened environmental sensitivity, within a diathesis-stress context, as it reflects increased psychopathology, in combination with environmental stress. Further, emotion regulation was found to be an important mediating factor, highlighting a potential treatment target for future mental health interventions, designed for high SPS individuals. Cognitive mechanisms, which support increased processing and responding to the environment, were also investigated within the context of SPS and different contextual learning tasks. However, no associations were observed between SPS and (i) statistical learning, (ii) global-local attentional processing biases, nor (iii) differences in reinforcement learning. Future research may benefit from undertaking neural measurements, such as by electroencephalogram (EEG), in order to assess cognitive mechanisms more directly.

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Declaration

This thesis comprises work conducted by Charlotte Jane Booth for the degree of Doctor of Philosophy, from the University of Oxford. Charlotte contributed significantly to the design, recruitment, data collection, analysis and dissemination of this work. One of the chapters in this thesis presents data collected as part of the CogBIAS longitudinal study (*Chapter 4*), which reflects a collaborative process with other members of the OCEAN lab. Charlotte was integral in all aspects of this study, including the design and recruitment of the participating schools. All other chapters in this thesis were conducted exclusively by Charlotte and recruited adult participants, either from around Oxford, or using online platforms. All of the chapters presented in this thesis were written exclusively by Charlotte, with draft versions read and commented on by Professor Elaine Fox, as well as other members of the OCEAN lab. None of the work in this thesis has been submitted for publication, although Charlotte will work towards this in the coming months during a one-year Post-Doctoral position at the University of Oxford.

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Chapter 1

1. Introduction

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Introduction

Life experiences have a huge impact on developmental outcomes, including psychological wellbeing. As humans, we need considerable support from caregivers during our relatively long period of childhood and adolescence. Developmental psychologists have long been interested in understanding the importance of environmental experiences on psychological outcomes, particularly the negative effects of childhood adversity. A stark example of this is the English and Romanian Adoptee (ERA) study, which assessed the development of 165 children adopted to the UK from severely deprived orphanages in Romania (Beckett et al., 2006). Compared to a control group adopted from the UK, it was found that Romanian adoptees displayed significant impairments in mental and social functioning across multiple time-points, which was attributed to their early experience of institutional deprivation. Impairment was less pronounced in children adopted before the first 6-months of life, suggesting that prolonged deprivation has more severe consequences.

While the significant impact of early experiences on developmental outcomes has been established, it has also been noted that individual differences moderate this effect. Theories of *Environmental Sensitivity* suggest that inter-individual variability in sensitivity predicts differential responsiveness to the environment (Pluess, 2015a). These inter-individual differences in environmental sensitivity – reflected by responding more or less to the

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environment – are seen across many species, including humans (Pluess). The strategy reflecting increased responsivity is regarded as metabolically costly, yet is considered advantageous to the individual and the group, when used by a minority of the population (Wolf, Van Doorn, & Weissing, 2008). This was highlighted in a computer simulation study, showing that the responsive strategy is negatively frequency dependent, as its benefits decrease with increasing numbers of responsive individuals (Wolf et al.). Such behavioural variation is thought to be a heritable manifestation of natural selection, with each strategy associated with different costs and benefits (Nettle, 2006).

In humans, markers of heightened environmental sensitivity have been shown to moderate the effect of the environment, reflected by increased responsivity to its effects, resulting in extreme outcomes (Belsky & Pluess, 2009). A typical moderation model of environmental sensitivity is depicted in **Figure 1**, whereby the effect of an environmental predictor on an outcome, is tested at different levels of a marker of environmental sensitivity. This marker could reflect a genetic polymorphism, or be tested at high and low levels of a phenotypic trait. Research suggests that individuals are more or less responsive to the effects of the environment, depending on their level of environmental sensitivity (Belsky & Pluess). For example, it has been found that individuals carrying a short allele of the serotonin transporter gene (5-HTTLPR) show heightened environmental sensitivity, reflected by extreme mood outcomes in response to environmental stress, particularly childhood maltreatment (Karg, Burmeister, Shedden, & Sen, 2011). Although this finding has been replicated many times, it has not always been supported, with a few studies finding that the long allele reflects heightened sensitivity (Sharpley, Palanisamy, Glyde, Dillingham, & Agnew, 2014). This has sparked much debate on the credibility of candidate gene studies, with the field of psychiatric genetics moving towards whole genome wide approaches instead

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(Assary, Vincent, Keers, & Pluess, 2017). Less research has been carried out on phenotypic markers of environmental sensitivity, which was the focus of this thesis.

The current thesis investigates a phenotypic marker of environmental sensitivity, known as *Sensory-Processing Sensitivity*, which is thought to be a biologically driven trait, reflecting heightened environmental sensitivity (Aron, Aron, & Jagiellowicz, 2012). *Part one* of the thesis investigates how this trait moderates the effect of the environment on psychological outcomes in adults (*Chapters 2 & 3*) and adolescents (*Chapter 4*). *Part two* of the thesis investigates whether this trait is associated with different cognitive mechanisms, which may underlie heightened sensitivity to the environment (*Chapters 5 & 6*). A general discussion of the thesis is provided in *Chapter 7*.

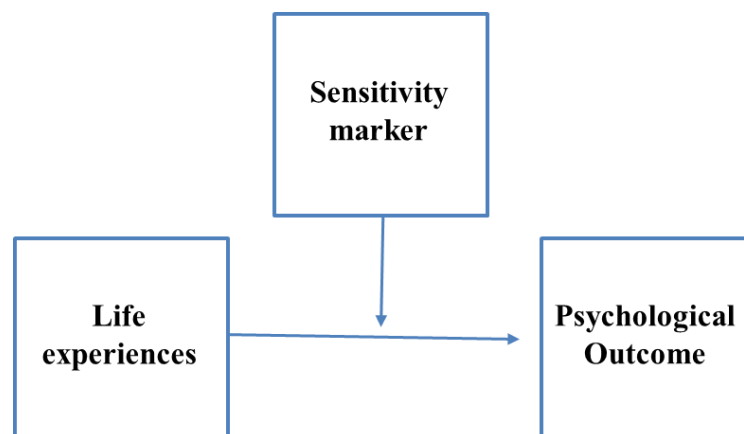


Figure 1. *Typical moderation model of Environmental Sensitivity depicting some sensitivity marker (e.g., phenotypic or genetic individual difference) moderating the effect of life experiences on some psychological outcome.*

Psychological Outcomes

In this thesis I was interested in assessing a full range of mood-related psychological outcomes, including mental illness and mental health, in order to gain a better understanding

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of different pathways to mental illness and wellness. Traditionally, psychology has focused on understanding the workings of mental illness, which has led to the development of a comprehensive framework of disorders. The most recent Diagnostic Statistical Manual for clinicians (DSM-5) describes 157 different diagnosable mental disorders (American Psychiatric Association, 2013). Mental illness is associated with significant impairment and distress to the affected individual and their family/friends, as well as significant costs to society, due to loss of productive working days (Keyes, 2002; Stewart, Ricci, Chee, Hahn, & Morganstein, 2003). It has been estimated that half of the population will meet criteria for a mental disorder at some point in their lives and that half of such cases will start by the age of 14 years (Kessler et al., 2005). In this thesis, I focused on depression as an outcome representing mental illness.

The most common form of depression is Major Depressive Disorder (MDD), also known as unipolar depression, which is thought to affect approximately 17% of the population at some point in their lives (Kessler et al., 2005). Most of these cases will have experienced first onset of MDD before the age of 18 years (Kessler et al., 2005; Merikangas et al., 2010). MDD is considered a serious and recurrent mental illness, associated with significant impairment in functioning and quality of life, as well as early mortality and attempted suicide (Kessler & Bromet, 2013; Lewinsohn, Rohde, & Seeley, 1998; Üstün, Ayuso-Mateos, Chatterji, Mathers, & Murray, 2018). The World Health Organization (WHO) estimated depression to be the fourth leading cause of disease burden worldwide in the year 2000 and projected it would be the second leading cause by the year 2020 (Murray & Lopez, 1996). According to the DSM-5, a diagnosis for MDD is based on a number of symptoms being present consistently for at least two weeks. At least one of two symptoms related to ‘anhedonia’ must be present, as well as at least a further four symptoms related to changes in behaviour or impairments in functioning. **Table 1** presents an overview of these

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symptoms and diagnostic criteria. We assessed depression with the Patient Health Questionnaire (PHQ-9), which is a self-report measure of the severity of each of these symptoms rated on a 4-point scale (Spitzer, Kroenke, & Williams, 1999).

Table 1. *Symptoms of Major Depressive Disorder (MDD) according to DSM-5*

Diagnostic criteria	Symptom description
<i>Anhedonia</i> : requires at least one symptom to be present for at least 2 weeks (Symptoms 1 or 2)	1. Depressed mood most of the day 2. Diminished interest or pleasure in all or most activities 3. Significant unintentional weight loss or weight gain
<i>Change/impairments in functioning</i> : at least four further symptoms present for same period of time (Symptoms 3-9)	4. Insomnia or sleeping too much 5. Agitation or psychomotor retardation noticed by others 6. Fatigue or loss of energy 7. Feelings of worthlessness or excessive guilt 8. Diminished ability to think or concentrate, or indecisiveness 9. Recurrent thoughts of death

I was also interested in assessing positive mental health, as solely focusing on mental illness impedes and narrows the understanding of individual differences in wellbeing. Mental health has been conceptualised as positive and distinct from mental illness (Keyes, 2002, 2005). This approach considers mental health on a continuum, with those experiencing high levels considered to be in a state of ‘flourishing’, those experiencing low levels considered to be in a state of ‘languishing’, and those in the middle considered to be experiencing ‘moderate mental health’. In a similar way as depression, positive mental health (flourishing) can be understood and operationalised by the presence of a number of positive symptoms, including features of ‘hedonia’ and symptoms related to positive functioning. This can be

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measured by self-report with the *Mental Health Continuum* (MHC) (Keyes). Flourishing is depicted by individuals reporting high (upper tercile) levels of hedonia (e.g., positive affect or life satisfaction), as well as high levels of positive functioning related to psychological and social wellbeing. **Table 2** presents an overview of these symptoms and criteria. The MHC has been shown to correlate negatively with symptom level measures of depression, yet is thought to reflect a distinct concept, which has been supported by confirmatory factor analyses (Keyes).

Table 2. *Symptoms of Flourishing Mental Health (Keyes, 2005)*

Diagnostic criteria	Symptom description
<i>Hedonia</i> : requires high level on at least one symptom scale (Symptoms 1 or 2)	1. Regularly cheerful, happy, calm (<i>positive affect past 30 days</i>) 2. Feels happy or satisfied with life overall (<i>avowed life satisfaction</i>)
<i>Positive functioning</i> : requires high level on six or more symptom scales (Symptoms 3-13)	3. Holds positive attitudes toward oneself and past life (<i>self-acceptance</i>) 4. Has positive attitude toward others (<i>social acceptance</i>) 5. Shows insight into own potential and open to new challenging experiences (<i>personal growth</i>) 6. Believes that people, groups and society have potential and can evolve (<i>social actualisation</i>) 7. Holds goals and beliefs that affirm sense of direction, purpose and meaning (<i>purpose in life</i>) 8. Feels that one is useful to society and that his/her actions are valued by others (<i>social contribution</i>) 9. Exhibits capability to manage complex environment (<i>environmental mastery</i>)

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10. Interested in society or social life; feels society is somewhat logical and meaningful (*social coherence*)

11. Exhibits self-direction that is guided by his/her own social standards (*autonomy*)

12. Has warm trusting relationships with others (*positive relations with others*)

13. Has a sense of belonging to a community to derive comfort from (*social integration*)

Environmental Predictors

Childhood experiences are fundamental in shaping developmental outcomes. Most research has focused on negative childhood experiences predicting poor health outcomes, such as depression. Less is known about positive childhood experiences that predict adaptive functioning, such as flourishing. For example, the Adverse Childhood Experiences (ACE) study assessed medical records for 9,508 individuals who also completed a questionnaire regarding experiences of ACE, including early psychological abuse, physical abuse, sexual abuse, exposure to violence and household dysfunction (Felitti et al., 1998). They found that increasing levels of ACE predicted increased risk for disease and early mortality from outcomes such as depression, obesity, drug use, cancer, heart disease and stroke. The authors proposed a stepwise model whereby ACE lead to social, emotional and cognitive impairments, leading to the adoption of health-risk behaviours, leading to disease, disability and social problems, and ultimately to early mortality.

Negative childhood experiences have also been examined in models specifically predicting increased risk for depression. Emotional and physical neglect, as well as sexual abuse and death of a parent in childhood have been proposed as potent risk factors (Hill,

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2009). Research often relies on retrospective measures of childhood experiences, such as the *Childhood Trauma Questionnaire* (CTQ; Bernstein et al., 2003), which assesses physical abuse, sexual abuse, emotional and physical neglect. A study in depressed patients ($N = 349$) found elevated levels of emotional neglect and sexual abuse compared with levels in the general population (Negele, Kaufhold, Kallenbach, & Leuzinger-Bohleber, 2015). However, caution must be taken when interpreting cross-sectional research that relies on retrospective measures, as such designs may inflate the estimated relationship. For example, depressed patients may have a bias to remember more negative events (Gotlib & Joormann, 2010). Further, the direction of the relationship is unclear, as parental neglect could be the result of parental depression, therefore elevated depression in their children could indicate an inherited vulnerability, as well as being the result of neglect (Hill, 2009).

The causal effect of negative childhood experiences on depression has been better established using prospective longitudinal designs. Using federal court documents, Widom, DuMont, and Czaja (2007) recruited a group of abused or neglected children ($n = 676$) and compared them with a control group matched on age, sex, ethnicity and social class, but who were not abused ($n = 520$). Clinical interviews conducted over 20 years later, when participants were around 30 years old, indicated elevated levels of depression in the abused group. Specifically, 25% of the abused group had experienced an episode of MDD, compared with 20% of the controls. Depression was also more severe in the abused group, as for those who did experience depression, the abused group reported on average twice as many episodes in their lifetime compared to controls. While this establishes the impact of childhood maltreatment on depression, it does not explain the mechanisms of action.

The negative psychological effects of childhood maltreatment can be explained by various intermediary mechanisms. In a sample of acute and remitted depressed individuals

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($N = 340$), Schierholz, Krüger, Barenbrügge, and Ehring (2016) found that difficulties in emotion regulation, insecure attachment style and negative attributional style mediated the pathway between childhood maltreatment and depression. This provides an explanation for how negative childhood experiences can lead to later depression, as fundamental skills associated with emotion regulation and social bonding are not developed, putting individuals at risk for developing psychopathology.

Integrative aetiological models of depression can explain these complex pathways further (Lewinsohn, Hoberman, Teri, & Hautzinger, 1985; Lewinsohn et al., 1998). Depression is regarded as the end result of environmentally initiated changes in cognition, affect and behaviour. Negative experiences, including daily hassles and significant traumatic experiences, are thought to trigger negative affective cognitions and disrupt adaptive behaviours. Persistent negative cognitions and decreased positive interactions are thought to increase negative affect and maintain cognitive and behavioural changes associated with depression. Individual differences are thought to moderate these relationships, as the negative effects resulting from negative experiences are thought to be worse for more environmentally sensitive individuals.

Less is known about specific positive childhood experiences, which lead to adaptive psychological functioning. Yet, in the same way that negative affect leads to psychopathology, positive affect is thought to lead to mental wellbeing. The broaden-and-build theory proposes that positive emotions broaden the thought-action repertoire and build enduring psychological resources contributing to wellbeing (Fredrickson, 2001; Fredrickson & Joiner, 2002). In contrast to negative emotions, which narrow the thought-action repertoire (e.g., promoting fear and escape), positive emotions promote exploration and build creativity and important social resources, which have lasting effects on wellbeing. Therefore, childhood

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experiences involving a safe environment, where children can explore their passions and interests with the support of loving caregivers, should set the foundations for a developmental trajectory towards positive mental health.

The role of positive affect in developing mental health has been examined in studies assessing the effect of dampening of positive emotions. Dampening is regarded as the down-regulation of positive affect in response to positive experiences and has been implicated as a risk factor for depression (Wood, Heimpel, & Michela, 2003). In a study of 81 children aged 7 to 10 years, it was found that dampening of positive emotions in response to positive life events predicted higher levels of depressive symptoms (Gilbert, Luking, Pagliaccio, Luby, & Barch, 2017). Dampening of positive emotions has been explained as a way to maintain one's self-concept, as it has been linked to low levels of self-esteem (Wood et al.). Therefore, promoting children's self-esteem may be crucial, in order for them to be able to savour positive experiences and build towards more positive mental health. More research is needed from this positive standpoint, to elucidate specific positive experiences that elicit optimal wellbeing.

In this thesis, I assessed positive and negative childhood experiences in order to gain a better understanding of individual pathways to depression vulnerability and wellbeing. With adult samples (*Chapters 2 & 3*), I assessed retrospective experiences of parental care and support, as well as abuse and neglect. In an adolescent sample (*Chapter 4*), I assessed recent life events, both positive and negative, with a checklist measured at two different time points.

Individual Differences in Environmental Sensitivity

A number of theoretical models of environmental sensitivity have been developed to explain differential responsivity to the effects of the environment. They predict that certain

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individuals, due to varying genetic and personality profiles, display heightened levels of environmental sensitivity, which is evident by increased responsiveness to environmental effects, resulting in extreme outcomes. Models of environmental sensitivity that are relevant to this thesis are discussed below.

Diathesis-Stress

Diathesis-stress is a model of environmental sensitivity that describes heightened vulnerability for psychopathology. It has been prominent in the psychiatric literature for over fifty years, originally used to describe the aetiology of schizophrenia (Bleuler, 1963; Rosenthal, 1963). Psychiatric researchers had noted the heritable component of mental disorders, as it was observed that they were concordant within families. It had also been noted that stressful life experiences often preceded the onset of such disorders, but that some individuals were more affected by the effects of stress than others. Diathesis-stress predicts that inherent characteristics increase sensitivity to stressful life experiences, predicting increased risk for psychopathology. This model has since been applied to the aetiology of depression, suggesting that genetic factors increase risk for depression, when combined with increased levels of adverse life experiences (Monroe & Simons, 1991). This was originally supported by twin studies, which estimated a significant contribution of genetic and environmental factors predicting risk for depression, e.g., twin studies estimate that depression is explained by 40% additive genetic variance and 60% non-shared environmental variance (Sullivan, Neale, & Kendler, 2000). Diathesis-stress was originally used to explain the findings of an early gene-by-environment (G x E) interaction study, which found increased responsiveness to the effects of maladaptive stress predicting increased risk for depression, in individuals carrying the short allele of the 5-HTTLPR gene (Caspi et al., 2003). Although this effect has since be considered within a differential susceptibility framework

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instead (Belsky & Pluess, 2009), as individuals homozygous for the short allele also appeared to show somewhat better outcomes in the absence of stressful life events.

Differential Susceptibility

Differential susceptibility theory (Belsky, 1997, 2005) predicts that certain inherent characteristics increase responsivity to both positive *and* negative experiences. It proposes that traits that only increase responsivity to negative experiences (as described in diathesis-stress) are not likely to be prevalent in the population, due to evolutionary pressure from natural selection. Thus, heightened sensitivity is regarded as a general mechanism, which carries an advantage in certain positive environments, as well as carrying a disadvantage in certain negative environments. It is based on the notion that developmental environments, such as levels of environmental stress, are uncertain. Therefore, populations which are diverse in their levels of environmental sensitivity, will be better equipped to deal with the uncertainty of the environment. During times of extreme stress, the less sensitive individuals are expected to fare better than the highly sensitive, whereas during times of low stress and increasing environmental support, the highly sensitive individuals are expected to flourish and surpass the low sensitive individuals in terms of adaptive functioning. Therefore, instead of heightened sensitivity being regarded as a risk factor (as in diathesis-stress), differential susceptibility proposes that it is a *plasticity* factor, reflected by increased sensitivity to the environment in general. This model has been supported by many G x E studies, including single candidate gene studies (Caspi et al., 2002; Eley et al., 2004; Taylor et al., 2006), and polygenic candidate gene studies (Belsky & Beaver, 2011; Bousman, Gunn, Potiriadis, & Everall, 2016; Cicchetti & Rogosch, 2012), finding that certain genetic profiles reflect plasticity, as they reflect more positive outcomes in relation to positive experiences, as well as reflecting more negative outcomes in relation to negative experiences. It has also been

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supported by studies examining temperament traits, finding that negative emotionality and difficult childhood temperament can be regarded as a plasticity factor, conferring ‘for better and for worse’ outcomes relative to the developmental environment (Slagt, Dubas, Deković, & van Aken, 2016; Slagt, Dubas, Denissen, Deković, & van Aken, 2015).

Vantage Sensitivity

Vantage sensitivity is a new model of environmental sensitivity describing differential responsiveness to positive experiences (Pluess, 2015b; Pluess & Belsky, 2013). This model can be regarded as the flipside to diathesis-stress, which describes differential responsiveness to negative experiences only. Vantage sensitivity describes heightened responsiveness to the influence of positive experiences only. The concept was developed to provide a theoretical model, which could be used to explain differential responsiveness to positive environmental manipulations, such as psychological interventions. Individuals who display significantly better responses are considered to show increased vantage sensitivity. Examples of studies that have shown vantage sensitivity include individuals carrying the short allele of the 5-HTTLPR gene showing better outcomes in response to a psychological intervention (Eley et al., 2011), as well as in response to high quality foster care (Drury et al., 2012).

Biological Sensitivity to Context

Biological sensitivity to context is a model of environmental sensitivity, which is similar to differential susceptibility, as it predicts ‘for better and for worse’ outcomes in highly reactive individuals, relative to the influence of environmental stress (Boyce & Ellis, 2005). In this model, heightened stress reactivity is regarded as the key mechanism, which exerts differential responsiveness to the environment. Biological sensitivity to context proposes that stress reactivity is a phenotype, which develops through interaction between genes and early life experiences. The stress response system is thought to initially reflect plasticity, while

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gradually becoming canalised, into a stable individual difference characteristic. Although not much research has been done in humans, it is thought that the early years from 3 to 5, may have particular effects on the calibration of the stress response system. Heightened stress reactivity is thought to reflect biological sensitivity to context, as it corresponds to worse physical and psychological outcomes in combination with high stress environments, while also reflecting better outcomes in the absence of stress (Boyce et al., 1995; Gannon, Banks, Shelton, & Luchetta, 1989). While the hypothesised interaction and outcome trajectory is the same as differential susceptibility theory, there are key differences in the definition of reactivity and of its origin. Biological sensitivity to context proposes that reactivity in one or more of the neurobiological stress response systems, which originates from early stressful life experiences, moderates the environment. While, differential susceptibility theory proposes that it is a genetically determined trait, which exerts differential responsiveness to the environment (Belsky, 1997).

Integrative model

Although these models of environmental sensitivity were developed from different backgrounds, they share similar underlying assumptions regarding variation in responsiveness to the environment – that some individuals are more responsive than others. Further, studies which support these theoretical models often reflect the same trait, for example the short allele of the 5-HTTLPR gene, which has been used as an example to support each of these models. Given these similarities, a meta-framework has recently been suggested to integrate these models (Pluess, 2015a). **Figure 2** illustrates this integrated model, whereby diathesis-stress reflects instances of differential responsiveness to negative experiences, vantage sensitivity reflects instances of differential responsiveness to positive experiences, and differential susceptibility reflects differential responsiveness to both positive and negative

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experiences. Biological sensitivity to context would predict the same outcome trajectory as differential susceptibility, relative to the influence of a positive or negative experience. Yet differential susceptibility provides a more comprehensive theory, as it incorporates many different levels for the marker of environmental sensitivity (e.g., genotypic, endophenotypic, and phenotypic), whereas biological sensitivity to context implicates heightened stress reactivity as the specific marker of environmental sensitivity.

Not all markers of environmental sensitivity are expected to moderate both positive and negative experiences. It is possible that some traits reflect heightened sensitivity to purely negative experiences, and vice versa. Although, in order to test the full model (i.e., differential susceptibility), it is important to test differential responsiveness to both positive and negative experiences within the same study. Many previous studies have focused on the assessment of purely negative experiences, which is related to the fact that individual differences research has been biased towards the measurement of psychopathology, as opposed to understanding mental wellbeing (Belsky & Pluess, 2009). Research conducted as part of this thesis was informed from the perspective of differential susceptibility, which is reflected in the full spectrum of measures taken.

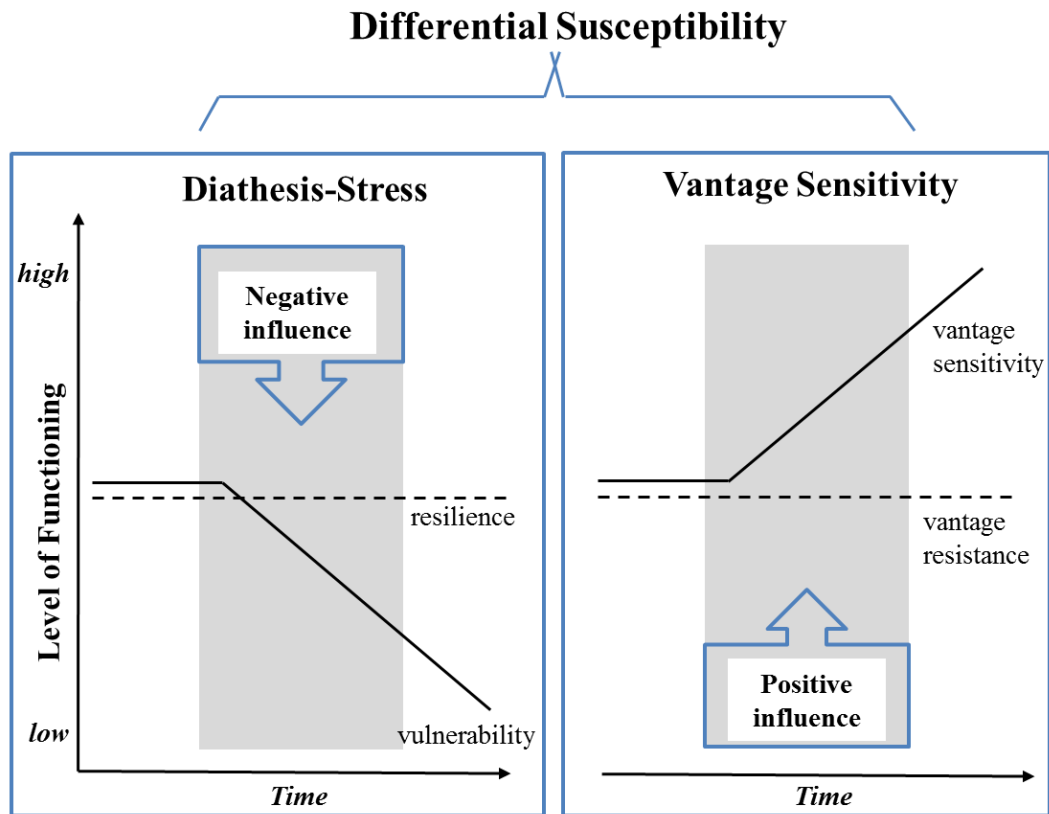


Figure 2. *Integrated conceptualisation of the different models of environmental sensitivity (from Pluess, 2015a), including diathesis-stress responses to negative experiences, vantage sensitivity responses to positive experiences and the overarching model of differential susceptibility.*

Sensory-Processing Sensitivity

Sensory-Processing Sensitivity (SPS) is another theoretical model of environmental sensitivity, although it is the only one which describes a particular adult personality trait. The notion of SPS was developed to provide an empirical understanding of the popular concept of ‘sensitivity’, which has been used in clinical settings and throughout society to describe individuals who are highly reactive to experiences (Aron & Aron, 1997; Aron et al., 2012). Sensitivity to the environment had been alluded to in earlier models of personality. Eysenck’s

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model features the ‘introversion-extraversion’ dimension, describing highly introverted individuals as easily over-aroused by environmental stimuli, such as social interactions, therefore preferring low-arousal environments, such as solitary activities (H. J. Eysenck, 1957, 1963). Gray’s model features the Behavioural Inhibition System (BIS), which regulates competing motivations from the Behavioural Activation System (BAS) and the ‘fight-flight-freeze’ system to decide upon a course of action, e.g., approach or avoid (Gray, 1982; Gray & McNaughton, 2003). Individuals exhibiting high levels of BIS are described as highly sensitive to punishment and vulnerable to negative emotions, such as anxiety (Gray, 1982). Also, Kagan’s model of temperament describes ‘behaviourally inhibited’ children, as those who are more sensitive to environmental stimulation and likely to be cautious in novel situations, e.g., interacting with unfamiliar people (Kagan, 1989). Based on these foundations, Aron & Aron developed the concept of SPS to capture sensitivity in adult personality, although SPS is thought to be stable across the lifespan, and measures have now been developed for children (Pluess et al., 2018).

The first paper on SPS described the development of a questionnaire to capture the concept of SPS in adults (Aron & Aron, 1997). It was developed based on qualitative interviews with individuals who described themselves as ‘sensitive’. Thirty-five adults completed in-depth interviews about their lives and attitudes, as well as completing some psychometric measures. Several overarching themes emerged, such as having a deep connection with spirituality and the arts, as well as a tendency to become overwhelmed by increasing stimulation. A 60-item questionnaire was developed to capture these diverse themes, which was later reduced to a 27-item questionnaire, which was psychometrically tested across six different samples. The *Highly Sensitive Person Scale* (HSPS) contains diverse items, such as noticing subtleties in the environment, being more sensitive to caffeine and pain, being deeply moved by the arts or music, and becoming unpleasantly aroused by

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increasing stimulation. The original study found that the HSPS showed good internal consistency and appeared to be capturing a unidimensional trait (Aron & Aron).

In more recent years, the unidimensionality of the HSPS has been questioned, with many different researchers consistently finding a three-factor solution (Booth, Standage, & Fox, 2015; Pluess et al., 2018; Smolewska, McCabe, & Woody, 2006). The three factors are known as *Ease of Excitation* (EOE), *Low Sensory Threshold* (LST), and *Aesthetic Sensitivity* (AES). EOE refers to becoming easily overwhelmed by increasing stimulation (e.g., “Do you get rattled when you have a lot to do in a short amount of time?”). LST refers to the tendency for experiencing unpleasant arousal in response to strong sensory input (e.g., “Are you bothered by intense stimuli, like loud noises or chaotic scenes?”). Finally, AES refers to heightened sensitivity to more positive stimuli (e.g., “Are you deeply moved by the arts or music?”). Despite the three-factor structure of the HSPS, it is considered to capture a higher order construct reflecting SPS (Aron, Aron, & Jagiellowicz, 2012), which is supported by the fact that the three factors are highly correlated. However, AES is less correlated with the other factors and with the total scale. Further, AES has been shown to correlate with other positive traits, such as openness to experience and positive emotionality, while EOE and LST have been shown to correlate with more negative traits, such as neuroticism and negative emotionality (Pluess et al.; Smolewska et al., 2006; Sobocko & Zelenski, 2015). The HSPS has been criticised for being biased towards the measurement of negative reactivity (i.e., most items load onto the EOE and LST factor) (Aron, Aron, & Jagiellowicz). Although, the aim of this thesis was to investigate SPS as a broad concept, therefore the primary research questions were assessed by investigating SPS as a unidimensional construct.

SPS, as measured with the HSPS, has shown good convergent and discriminant validity with other measures. The original study reported small to moderate positive

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correlations with different measures of introversion and emotionality (Aron & Aron, 1997). A later study (Smolewska et al., 2006) assessed the HSPS in relation to the Big-Five traits (Costa & MacCrae, 1992) and the BIS/BAS scale (Carver & White, 1994). SPS showed a moderate positive correlation with ‘Neuroticism’ and a small positive correlation with ‘Openness’ from the Big-Five, suggesting that high SPS individuals are likely to be vulnerable to negative emotions, as well as being creative and open to non-traditional ideals. SPS also showed a moderate positive correlation with BIS and small positive correlation with BAS (subscale: reward responsiveness), suggesting that high SPS individuals are likely to be highly motivated by reward, but experience increased goal-conflict and sensitivity to punishment, thus exhibiting greater behavioural inhibition. The HSPS was recently adapted for use in child and adolescent samples (Pluess et al., 2018). This study supported the correlations with Neuroticism, Openness, BIS and BAS, but also observed a negative correlation between SPS and ‘Extraversion’, suggesting that high SPS adolescents are also likely to be more introverted.

Despite the correlations found with other traits, SPS has been shown to be a distinct construct. In the original study, the authors assessed partial correlations between sensitivity-related items and the HSPS score, controlling for introversion and emotionality (Aron & Aron, 1997). The sensitivity-related items remained significantly correlated with the HSPS score, even when controlling for introversion and emotionality, suggesting that the HSPS is capturing some distinct facet of sensitivity, which is independent of emotionality. More recently, multivariate regression analyses of different personality measures predicting SPS were performed across child and adolescent samples (Pluess et al., 2018). Together, the Big-Five traits explained just 14% of variance in SPS, while measures of BIS/BAS and positive/negative emotionality explained between 26% and 34% of variance, providing evidence of divergent validity.

SPS & Environmental Sensitivity

High SPS has been regarded as a trait reflecting heightened environmental sensitivity (Belsky & Pluess, 2009). It was originally observed that high SPS individuals showed heightened responsivity to self-reported negative parenting quality in childhood predicting greater levels of unhappiness (Aron & Aron, 1997). This was later investigated in a study that used better validated measures of the environment and depression, finding that high SPS individuals were more responsive to the negative effects of low parental care, predicting higher levels of depression, in comparison to low SPS individuals (Liss, Timmel, Baxley, & Killingsworth, 2005). We have also previously examined whether SPS moderates the effect of negative childhood experiences on life satisfaction, finding that high SPS individuals were more sensitive to the environment, showing particularly low levels of life satisfaction in response to high levels of adversity (Booth et al., 2015). These three examples support the hypothesis that high SPS is a trait that reflects heightened environmental sensitivity, supporting a diathesis-stress framework.

Although recent evidence suggests that high SPS individuals may show heightened environmental sensitivity in a more general way, supporting differential susceptibility. A study in adolescents, for instance, found that high SPS individuals responded most favourably to a school-based resiliency intervention, as evidenced by decreasing levels of depression at two follow-up time points, supporting a vantage sensitivity framework (Pluess & Boniwell, 2015). A similar study evaluated change in levels of victimisation and internalising symptoms in a large randomised controlled anti-bullying trial in 2,000 Italian school children (Nocentini, Menesini, & Pluess, 2018). The results showed that victimisation and internalising symptoms were reduced in boys, but not girls, receiving the active treatment, and that SPS moderated this effect, as high SPS boys showed the greatest reduction

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in symptoms. Another study in pre-school children found that high SPS children displayed the highest levels of externalising behaviour in response to negative parenting and the lowest levels of externalising behaviour in response to positive parenting, supporting a differential susceptibility framework (Slagt, Dubas, van Aken, Ellis, & Deković, 2018).

While SPS is the most commonly described phenotypic trait reflecting heightened environmental sensitivity in adults, other child temperament traits have shown individual differences in environmental sensitivity. Drawing on empirical evidence from the developmental literature, Belsky (2005) found that difficult and negative child temperament traits were candidate markers, as they predicted ‘for better and for worse’ outcomes relative to positive and negative rearing influences, supporting his model of differential susceptibility. A recent meta-analysis of 84 different studies supported this finding, as it was shown that difficult temperament and negative emotionality (but not surgency or effortful control), reflected heightened sensitivity to both positive and negative rearing influences, in line with differential susceptibility (Slagt et al., 2016). Children with high levels of difficult temperament and negative emotionality showed extreme outcomes in externalising and internalising symptoms, as well as social and cognitive competence, relative to their environment. For negative emotionality, these differential effects were moderated by age, as they were stronger in studies that assessed infants rather than older children. This calls into question whether there are windows of opportunity for differential susceptibility to take place, and whether children with high negative emotionality develop a more fixed phenotype depending on their early life experiences.

More research is needed on SPS, to establish whether differential susceptibility can be observed in adult populations. The HSPS is the only self-report measure reflecting environmental sensitivity in adults, therefore it is useful and easily applicable to many

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research designs (Belsky & Pluess, 2009; Pluess, 2015a). However, it remains unclear which framework best describes this trait, as earlier studies supported diathesis-stress (Aron & Aron, 1997; Booth et al., 2015; Liss et al., 2005), while later studies in adolescents, suggested differential susceptibility (Nocentini et al., 2018; Pluess & Boniwell, 2015; Slagt et al., 2018). One problem with the earlier studies in adults was the focus on assessing responsivity to negative experiences, without examining responsivity to positive experiences. In this thesis, I therefore wanted to investigate whether SPS moderates the effect of positive *and* negative experiences, in samples of adults (*Chapters 2 & 3*), as well as adolescents (*Chapter 4*).

Mechanisms & SPS

Understanding the mechanisms underlying heightened environmental sensitivity is important. It has been proposed that a “major goal of research on differential susceptibility to the environment is uncovering a high-resolution map of the mechanisms of context sensitivity” (Ellis & Boyce, 2011, p.2). SPS in itself may provide a mechanism of environmental sensitivity, however most research on SPS has assessed its association with other self-report variables. It has been proposed that SPS is related to greater awareness of environmental subtleties, deeper cognitive processing, and greater reflection upon experiences, due to underlying heightened levels of emotional reactivity (Aron, Aron, Jagiellowicz, 2012). Yet, more research is needed assessing the neuro-cognitive underpinnings of SPS to support these predictions.

A few studies have been conducted thus far. In one fMRI study, high SPS individuals showed greater neural activation in response to subtle changes in visual scenes, in areas associated with visual attention and processing (Jagiellowicz et al., 2011). In another fMRI study, high SPS individuals showed greater neural activity in response to viewing facial expressions of their loved ones compared with strangers with the same expressions, in areas

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associated with empathy, and general awareness (Acevedo et al., 2014). High SPS individuals have also shown enhanced performance, as evidenced by faster reaction-times and fewer errors, on a standard visual search task (Gerstenberg, 2012). Yet, more research is needed to elucidate the cognitive underpinnings that support heightened environmental sensitivity, associated with SPS. In this thesis, I investigated the association between SPS and implicit statistical learning, using a modification of a standard visual search task, in order to examine heightened environmental learning, as a general mechanism (*Chapter 5*). I also examined the association between SPS and a reinforcement learning paradigm, in order to investigate whether SPS was related to greater learning from either reward and/or punishment (*Chapter 6*).

Methods

Moderation

Testing models of environmental sensitivity often relies on the statistical method of moderation. Moderation refers to the differential effect of a predictor variable (X) on an outcome variable (Y), due to a moderator variable (Z). When the effect of X (e.g., childhood experiences) on Y (e.g., depression) is different as a function of Z (e.g., SPS), then moderation has taken place. In order to test for moderation, a normal multiple linear regression analysis is run including both the predictor and moderator variable, as well as their interaction (predictor*moderator) as predictors in the model (Aiken, West, & Reno, 1991). If the interaction is significant, then this is normally followed up with the simple slopes method, which tests the direction and strength of the effect of X on Y at high and low levels of the moderator variable (usually $\pm 1 SD$ from the mean). While this is the usual method for testing moderation, a better method has recently been described for testing differential susceptibility (Roisman et al., 2012).

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Regions of Significance (RoS) is an alternative method for following up significant interactions and is able to distinguish differential susceptibility from diathesis-stress (or vantage sensitivity) effects (Roisman et al., 2012). The ‘RoS on Z ’ test examines the range of values of Z for which X and Y are significantly associated. This is superior to the simple slopes method, as it doesn’t rely on arbitrary levels for testing moderation (e.g., at $\pm 1 SD$ from the mean of Z). The ‘RoS on X ’ test inverts the ‘RoS on Z ’ test to examine the range of values of X for which Z and Y are significantly associated. This test is superior to the simple slopes method, as rather than relying on visual inspection of the interaction, it tests at which levels of X the interaction is significant. This is particularly useful for cross-over interactions, as with the simple slopes method, it can be unclear whether a cross-over interaction truly represents differential susceptibility (issue depicted in **Figure 3**). If the association is only significant at low, but not high levels of X , this supports diathesis-stress. If the association is significant at high, but not low levels of X , this supports vantage sensitivity. If the association is significant at both high *and* low levels of X , this supports differential susceptibility. The advocates of this method also proposed an additional index that is useful for distinguishing differential susceptibility from diathesis-stress (or vantage sensitivity), known as the Proportion Affected (PA) index. This method calculates the proportion of the sample that show differential effects above the cross-over point of the interaction. Typically, PA indices of .50 suggest perfect differential susceptibility, while PA indices of .00 suggest perfect diathesis-stress.

It is important to note that other statistical methods, besides RoS analysis, have been proposed as superior to the simple slopes method for testing models of environmental sensitivity. The re-parameterised method was developed to test ordinal (i.e., non-crossover) versus disordinal (i.e., crossover) interactions, which is useful for assessing diathesis-stress versus differential susceptibility, which are expected to differ in this way respectively

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(Widaman et al., 2012). It works by re-parametrising the regression coefficient in order to estimate the crossover point along the predictor distribution. If the crossover point is within the range of values of the predictor, the interaction is disordinal, consistent with differential susceptibility. Conversely, if the crossover point is outside the bounds of the predictor, then the interaction is ordinal, reflecting diathesis-stress. This approach was described as superior to other more exploratory methods for testing interactions, as confirmatory analyses can be conducted to test model fit depending on different hypothesised interactions (Belsky, Pluess, & Widaman, 2013).

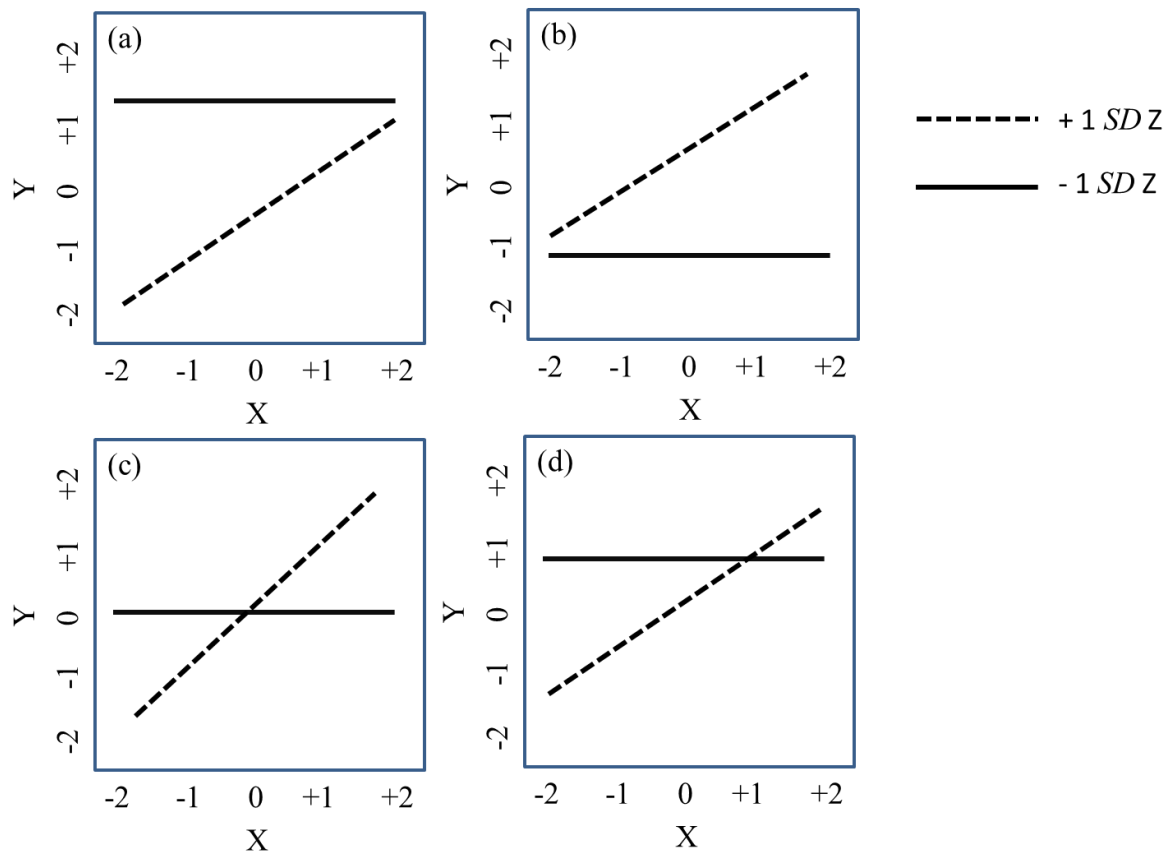


Figure 3. (a) *Prototypical diathesis-stress interaction*; (b) *Prototypical vantage sensitivity interaction*; (c) *Prototypical differential susceptibility interaction*; (d) *Ambiguous interaction (i.e., could be regarded as displaying either diathesis-stress or differential susceptibility by visual inspection alone)*. **Note:** *Y represents standardised values of the psychological outcome ranging from negative to positive, X represents standardised values of the environmental predictor ranging from negative to positive, Z is depicted at high and low levels of the marker of environmental sensitivity.*

Thesis Outline

The general aim of this thesis was to investigate different models of environmental sensitivity in relation to the personality trait SPS. The work in this thesis is divided in two parts: **Part one** (*Chapter 2, 3 & 4*) investigates whether SPS moderates the effect of positive and negative life experiences on psychological outcomes including wellbeing and depression symptoms across adult and adolescent samples; **Part two** (*Chapter 5 & 6*) investigates whether SPS associates with increased learning on different cognitive behavioural tasks in adult samples, which could provide evidence for mechanisms underlying heightened environmental sensitivity.

Part one

Chapter 2 tests a classic moderation model, whereby SPS moderates the effect of positive and negative childhood experiences on levels of wellbeing and job satisfaction in a healthy adult sample ($N = 339$). *Chapter 3* tests a moderated mediation model, whereby emotion regulation skills mediate the pathway between childhood experiences and wellbeing outcomes, while SPS moderates the effect of both childhood experiences on emotion regulation skills, as well as the effect of childhood experiences on wellbeing outcomes in a healthy adult sample ($N = 389$). Finally, *Chapter 4* investigates whether SPS moderates the effect of positive and negative life events on depression and wellbeing, in a healthy sample of adolescents taking part in a wider longitudinal study at Wave 1 ($N = 504$) and Wave 2 ($N = 450$).

Part two

Chapter 5 investigates whether SPS is associated with better visual statistical learning, as well as more of a local visual processing bias, across two samples of healthy adults ($N = 58$,

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$N = 79$). *Chapter 6* investigates whether SPS is associated with better learning from reward and/or punishment on a reinforcement learning task in a healthy sample of adults ($N = 397$).

Chapter 2

2. SPS & Life Outcomes

2

The Impact of Childhood Experiences on Life Outcomes across different levels of Sensory-Processing Sensitivity

Abstract: Differential susceptibility predicts that certain individual characteristics confer an adaptive benefit in conditions of environmental enrichment, as well as conferring maladaptive risk in conditions of environmental adversity. While this model has been supported in studies assessing genetic and child temperament susceptibility factors, it has not been well supported in studies of adult personality. *Sensory-Processing Sensitivity* (SPS) is an adult personality trait reflecting environmental sensitivity, although it is unclear whether it supports a differential susceptibility or diathesis-stress model of environmental sensitivity. This study investigated whether SPS would moderate the effect of positive and negative childhood experiences on life outcomes, including wellbeing and job satisfaction, using a cross-sectional design in an adult sample ($N = 339$). It was found that high SPS individuals displayed both the highest and lowest levels of wellbeing, relative to negative childhood experiences, which was consistent with differential susceptibility. However, in a separate model, it was found that low SPS individuals showed heightened responsiveness to positive experiences, consistent with vantage sensitivity. In conclusion, it was found that high SPS reflects heightened responsiveness to negative, but not positive childhood experiences, providing partial support for differential susceptibility. Future research should attempt to replicate these findings, as well as employ longitudinal designs, in order to investigate the direction of effects.

Introduction

Childhood experiences have a significant impact on developmental outcomes, but not everyone is impacted in the same way (Ellis & Boyce, 2011). Individual differences in environmental sensitivity predict differential responsivity to the environment (Belsky & Pluess, 2009, 2013; Pluess, 2015a). Diathesis-stress reflects an early theory of environmental sensitivity, positing that certain biological characteristics, such as genetic variants, predict increased risk for psychopathology under conditions of environmental adversity, e.g., life stress being more likely to lead to depression in those carrying putative risk factors (Monroe & Simons, 1991). A more recent theory, known as differential susceptibility (Belsky, 1997, 2005), has altered the notion of individual ‘risk’ factors to individual ‘plasticity’ factors, as it posits that certain traits confer increased environmental sensitivity more generally. Those that are highly sensitive to the environment are expected to show extreme negative outcomes in combination with adversity, as well as extreme positive outcomes in combination with enrichment. This pattern of results, consisting of a crossover interaction between the individual plasticity factor and experiences predicting some psychological outcome, has been well established in studies assessing plasticity at the genetic or child temperament level (Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Belsky & Pluess; Slagt et al., 2016). However, it has not been well supported in studies of adult personality, with the exception of one trait known as Sensory-Processing Sensitivity.

Sensory-Processing Sensitivity (SPS) is a personality trait thought to reflect environmental sensitivity. Aron and Aron (1997) developed SPS theory based on earlier personality research (Gunnar, 1994; Kagan, Snidman, Arcus, & Reznick, 1994) and related constructs, such as introversion (H. J. Eysenck, 1963) and behavioural inhibition (Gray, 1982). The basic premise is that certain individuals are highly sensitive to environmental stimuli, due to greater detection of subtleties in the environment, deeper cognitive processing

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strategies, more inhibited behaviour and heightened emotional reactivity (Aron et al., 2012). High SPS individuals are expected to show heightened responsivity to experiences leading to extreme outcomes, in comparison to low SPS individuals. This was originally supported by the fact that high SPS individuals – measured using the *Highly Sensitive Person Scale* (HSPS: Aron & Aron, 1997) – were more influenced by parenting quality predicting unhappiness in childhood. This was then supported in an independent study, showing that high SPS individuals reported greater depression in combination with poor parenting quality (Liss et al., 2005). We previously found complementary results, as high (relative to low) SPS individuals reported lower levels of life satisfaction in combination with negative childhood experiences (Booth et al., 2015). However, we failed to find a crossover interaction, as high SPS individuals did not report elevated life satisfaction in the absence of negative experiences, suggesting that high SPS may reflect a risk factor (i.e., diathesis-stress) rather than a plasticity factor.

Nevertheless, some experimental studies have found that high SPS individuals display heightened responsivity to positive experiences (Aron, Aron, & Davies, 2005; Pluess & Boniwell, 2015). High SPS university students were shown to report more positive affect compared to low SPS students, following an educational test in which it was perceived that they had performed well (Aron et al.). In another study, high SPS children relative to low SPS children showed a decrease in depressive symptoms following a school-based resiliency programme, with positive effects persisting at 6 and 12 month follow-ups (Pluess & Boniwell, 2015). Thus, failure to find greater life satisfaction in the absence of negative experiences in our previous study (Booth et al., 2015), may have been due to the limited measurement of positive experiences.

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The measurement of life experiences in psychological research is heavily biased towards the assessment of negative experiences, as opposed to positive experiences, which creates an obstacle for testing differential susceptibility (Belsky & Pluess, 2009; Manuck, 2010). Our previous study assessed childhood experiences with the *Risky Families Questionnaire* (RFQ: Taylor et al., 2006), which is an 11-item measure of experiences within the home and includes mostly negative items (> 70%). In the current study, we adapted the RFQ to include extra positive items that were matched to negative items, in order to gain a more in-depth measure of positive experiences. We also included *Maternal-Paternal Warmth and Coercive Parenting Scales*, as this has also been shown to have significant effects on developmental outcomes (Aquilino & Supple, 2001; Ellis, Schlomer, Tilley, & Butler, 2012). Psychometric analyses were performed on all of the measures of childhood experiences and composite measures for positive and negative experiences were created for the current study.

Our primary outcome variable was wellbeing, which was assessed with the *Mental Health Continuum* (MHC: Keyes, 2002), which is a composite measure of wellbeing, including the assessment of emotional, psychological and social wellbeing. It is based on the theory that mental health is not simply the absence of mental illness, as it can be operationalised by the presence of a number of wellbeing ‘symptoms’, which should be present for an extended period of time. The MHC was chosen as it encompasses multiple dimensions of wellbeing, as opposed to life satisfaction, which only measures hedonic wellbeing (Keyes, 2005).

A further aim of the study was to examine the impact of SPS and childhood experiences on a different outcome. If our previous findings were correct – that high SPS is a risk factor for low levels of wellbeing in combination with negative childhood experiences (Booth et al., 2015) – then it is possible that they will show differential outcomes in a different

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aspect of their life, such as in their career. High SPS individuals are thought to engage deeper cognitive processing strategies, which could lead to better job satisfaction, if given the opportunity of an enriching environment. Due to heightened environmental sensitivity, high SPS individuals are likely to avoid unpleasant working environments, which could lead them to choosing more fulfilling careers, especially if they experienced a supportive developmental environment. Therefore, although exploratory, we also assessed job satisfaction using the *Brief Index of Affective Job Satisfaction* (BIAJS: Thompson & Phua, 2012).

The current study sought to investigate the influence of retrospective childhood experiences (both positive and negative) on wellbeing and job satisfaction, moderated by SPS. A heterogeneous age group was tested, as SPS is considered a biologically driven trait, which is stable throughout the lifespan, therefore no assumptions about age-related differences were made. However, this could be considered a confounding factor in the current study, which relied on retrospective measures of childhood experiences, therefore analyses were conducted controlling for the effect of age. The aim of the study was to replicate and extend our previous findings (Booth et al., 2015). The design of the study was improved in comparison to our previous study by (i) taking more in-depth measures of childhood experiences and wellbeing, (ii) assessing an alternative psychological outcome besides wellbeing, and (iii) using Regions of Significance analyses to examine whether any crossover interactions truly represented differential susceptibility.

Probing significant interactions in moderated regression usually consists of the simple slopes method (Aiken et al., 1991) whereby the effect of X (e.g., experiences) on Y (e.g., wellbeing) is examined at varying levels of Z (e.g., SPS), usually at ± 1 standard deviations (SD) from the mean, in order to test the regression slope at high and low levels of the

moderator. While this method can test whether high SPS reflects heightened environmental sensitivity (i.e., a greater effect of X on Y) compared to low SPS, it cannot test at which level of X the slopes significantly differ. This can be problematic when trying to infer differential susceptibility, as any crossover interaction could be interpreted as reflecting differential susceptibility, despite the fact that all interactions have to crossover at some point. Regions of Significance (RoS) analyses (Dearing & Hamilton, 2006) have been recommended for moderated regression models testing differential susceptibility effects (Roisman et al., 2012). Specifically, the ‘RoS on X ’ test examines at which point of X the two plotted lines significantly differ. Differential susceptibility can be inferred when the crossover point of an interaction is around the mean of X and the two plotted lines of Z are in statistically different directions both above and below the mean of X .

Hypotheses

1. Increasing negative childhood experiences will predict decreasing wellbeing. This effect will be stronger in high compared to low SPS individuals.
2. Increasing positive childhood experiences will predict increasing wellbeing. This effect will be stronger in high compared to low SPS individuals.
3. Increasing negative childhood experiences will predict decreasing job satisfaction. This effect will be stronger in high compared to low SPS individuals.
4. Increasing positive childhood experiences will predict increasing job satisfaction. This effect will be stronger in high compared to low SPS individuals.

Method

Participants

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Participants were 339 adults who were recruited from an online database called *Prolific Academic*. They were reimbursed £1.70 for taking part in the survey. They displayed a heterogeneous age range (18 – 63 years, mean = 30.17, $SD = 9.21$). The sample was 53.1% male and 46.3% female (2 participants preferred not to say).

Measures

Demographics. Participants indicated their gender (male, female, prefer not to say), their age in years (free text box) and their highest level of completed education (1 = “Secondary school”, 2 = “Vocational/technical school”, 3 = “Some college”, 4 = “Bachelor’s degree”, 5 = “Master’s degree”, 6 = “Doctoral degree”).

The Highly Sensitive Person Scale – Short Form (HSPS-SF) (Pluess, Aron, & Aron, 2011) was used to measure SPS. It is a 12-item shortened version of the original 27-item scale (Aron & Aron, 1997). The two versions are highly correlated ($r = .94$) (Pluess et al., 2011). Participants were asked to rate each item about their personality using a 7-point scale (1 = “Not at all”, 7 = “Extremely”). Example items include “Do you seem to be aware of subtleties in your environment?”, “Do you have a rich complex inner life?” and “Do you make a point to avoid violent movies and TV shows?” Scores were mean averaged with high scores reflecting high SPS. The scale showed good internal consistency (Cronbach’s $\alpha = .81$).

The Adapted Risky Families Questionnaire (ARFQ) was developed for the current study based on the 11-item *Risky Families Questionnaire* (Taylor et al., 2006), which is a retrospective measure of childhood experiences. The original scale includes 8 negative childhood experiences (e.g., “How often did a parent or other adult in the household push, grab, shove, or slap you?”) and 3 positive experiences (e.g., “How often did a parent or other adult in the household express physical affection for you, such as hugging, or other physical gestures of warmth and affection?”). Five more positive experiences were added in an attempt

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to balance the scale to measure positive and negative events in equal measure. New positive items were created to match the negative items and focused on experiences that involved positive parental support and relationship quality, based on previous research (Belsky & Beaver, 2011). See Appendix A (pp. 52-24) for the full scale and psychometric properties. Participants were asked to think back to their childhood experiences prior to the age of 16 and answer each item using a 5-point scale ranging from 1 (“Not at all”) to 5 (“Very often”). Principal Components Analysis (PCA) found a clear two-factor structure, which differentiated between positive experiences and negative experiences. One new positive item did not load sufficiently onto either factor and was removed from further analysis, therefore the final subscales included 8 negative items and 7 positive items. Responses were summed to create a total score for positive experiences and a total score for negative experiences. Positive experiences showed excellent internal consistency (Cronbach’s $\alpha = .91$), as did negative experiences (Cronbach’s $\alpha = .90$).

Maternal-Paternal Warmth vs. Coercive Parenting (M-P-WCP) (Ellis, Schlomer, Tilley, & Butler, 2012) was used to assess parenting style in childhood for mothers and fathers respectively. The M-P-WCP was previously developed by combining 4-items of harsh/coercive parenting (e.g., “Insulted me or put me down”) from the *Conflicts Tactics Scale* (Jouriles, Mehta, McDonald, & Francis, 1997) and 12-items from the ‘Care’ subscale of the *Parental Bonding Instrument* (e.g., “Was affectionate to me” and “Seemed emotionally cold to me” – reverse scored) (Parker, Tupling, & Brown, 1979). Participants were asked to complete the same 16-item questionnaire for each of their parents using a 4-point scale (1 = “Very unlike”, 4 = “Very like”). Appendix B (pp. 55-57) shows the results of a PCA investigating the factor structure of the scales. Both mother and father scales displayed a three-factor structure, which included the same items, corresponding to *Coercive parenting* (e.g., “Acted in a way that made me afraid and that I might be physically hurt”), *Warm*

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parenting (e.g., “Was affectionate to me”) and *Cold parenting* (e.g., “Did not talk with me very much”). Therefore, the M-P-WCP scale assessed two dissociable negative parenting styles – *Coercive* and *Cold* parenting – and one positive style – *Warm* parenting. These subscales showed good/excellent internal consistency; coercive parenting (Cronbach’s $\alpha = .91$ and $.90$), warm parenting (Cronbach’s $\alpha = .90$ and $.92$), cold parenting (Cronbach’s $\alpha = .85$ and $.90$) for fathers and mothers respectively.

Positive and Negative Childhood Experiences. We created a composite measure of positive and negative childhood experiences using subscales from the ARFQ and M-P-WCP. The positive experiences subscale from the ARFQ and the warm parenting subscale for mothers and fathers from the M-P-WCP made up the positive experiences composite and the negative experiences subscale from the ARFQ and the coercive and cold parenting subscales for mothers and fathers from the M-P-WCP made up the negative experiences composite. We first converted the raw scores for each of the 8 subscales into z-scores and then computed the mean of the three scales corresponding to positive experiences and the mean of the five scales corresponding to negative experiences, resulting in a standardised composite score for positive childhood experiences and the same for negative childhood experiences. Internal consistency was good for positive (Cronbach’s $\alpha = .81$) and negative (Cronbach’s $\alpha = .85$) composites.

The Mental Health Continuum (MHC) (Keyes, 2002), is a 40-item composite measure of wellbeing including emotional, psychological and social wellbeing subscales. Emotional wellbeing (EWB) measures the frequency of experienced emotions (e.g., “cheerful”, “in good spirits”, “satisfied”) during the past 30 days. Psychological wellbeing (PWB) measures general personal wellbeing (e.g., “I am good at managing the responsibilities of everyday life”, “I like most parts of my personality”). Social wellbeing (SWB) captures wellbeing

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within society (e.g., “the world is becoming a better place for everyone”, “I have nothing to contribute to society” – reverse scored). A total wellbeing score was created by summing the items, with high scores reflecting wellbeing and low scores reflecting languishing. Internal consistency was adequate (Cronbach’s $\alpha = .70$).

The Brief Index of Affective Job Satisfaction (BIAJS) (E. R. Thompson & Phua, 2012) is a 4-item measure of job satisfaction. Example items include “I find real enjoyment in my job” and “Most days I am enthusiastic about my job”. It was only shown to participants who reported being in full-time work currently or working part-time and not seeking other employment ($N = 223$). Participants rated each item on a 5-point scale (1 = “Strongly disagree”, 5 = “Strongly agree”). Scores were summed with high numbers reflecting high levels of job satisfaction. Internal consistency was excellent (Cronbach’s $\alpha = .91$).

Salary. Participants who completed the BIAJS were also asked which salary range they fit in to: “1 = £10,000 - £18,000” (14.3%), “2 = £18,001 - £23,000” (9.0%), “3 = £23,001 - £27,000” (5.7%), “4 = £27,001 - £33,000” (6.3%), “5 = £33,001 - £40,000” (7.2%), “6 = £40,001 - £50,000” (6.6%), “7 = £50,001 - £75,000” (6.9%), “8 = £75,001 - £100,000” (3.0%) and “9 = £100,000 +” (1.2%).

Procedure

The study was advertised on *Prolific Academic* and recruited participants aged 18 – 65 who spoke English as a first language and were not currently suffering with a mental health disorder. Participants read a detailed information sheet and consent form before proceeding to the survey. The survey was delivered through *Limesurvey*. The questionnaires were presented in the following order (demographics, HSPS-SF, ARFQ, M-P-WCP, MHC, BIAJS, Salary). At the end of the survey participants were re-directed to *Prolific Academic* and received £1.70 reimbursement.

Statistics

We tested four moderated regression models in SPSS to investigate the independent and interactive effect of SPS and childhood experiences (both negative and positive) on wellbeing and job satisfaction respectively. Model 1 tested the independent and interactive effects of SPS and negative experiences on wellbeing. Model 2 tested the independent and interactive effects of SPS and positive experiences on wellbeing. Model 3 tested the independent and interactive effects of SPS and negative experiences on job satisfaction. Model 4 tested the independent and interactive effects of SPS and positive experiences on job satisfaction. Age and gender were controlled for in all regression models.

We followed up significant interactions in line with recommendations for testing differential susceptibility effects using RoS analyses (Roisman et al., 2012). All variables were standardised prior to analysis and tested within the bounds of ± 2 SDs. Analyses were run using a freely available web based program (<http://www.yourpersonality.net/interaction/>). ‘RoS on Z’ tests the range of values of the moderator where the predictor and outcome are significantly associated. Slopes were plotted at high and low levels of the moderator (± 1 SD from mean) to assess the strength and direction of effects. ‘RoS on X’ tests the range of values of the predictor where the moderator and outcome are significantly associated. This test is particularly useful for assessing models of environmental sensitivity, as in the case of crossover interactions, it is possible to assess the statistical significance of the differential effects. Significance at high and low levels of the predictor in a crossover interaction provides evidence for differential susceptibility. A Proportion Affected (PA) index was also computed to test the proportion of the sample showing differential effects above the crossover point of the interaction. PA indices around

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0.5 show evidence for differential susceptibility, while PA indices around 1.0 show evidence for diathesis-stress or vantage sensitivity (depending on the predictor measured).

Results

Descriptive statistics and correlations

Descriptive statistics and bivariate correlations for all variables are presented in **Table 1**. Age showed a small positive correlation with education level and a moderate positive correlation with salary. Gender showed a small correlation with wellbeing, as women reported lower levels. Education showed a small to moderate positive correlation with salary and a small positive correlation with positive childhood experiences. Wellbeing showed a small to moderate negative correlation with both SPS and negative childhood experiences. SPS showed a small positive correlation with negative childhood experiences. Finally, positive and negative childhood experiences showed a large negative correlation.

Table 1. *Descriptive statistics and bivariate correlations between all variables (N = 339)*

	<i>M (SD)</i>	1	2	3	4	5	6	7	8
1. Age	30.2 (9.2)	-							
2. Gender (male)	53.1%	.08	-						
3. Education level	2.9 (1.0)	.24*	.13	-					
4. Salary level	3.6 (2.5)	.42*	.00	.30*	-				
5. Wellbeing	147.9 (17.1)	-.01	.22*	-.08	-.10	-			
6. Job satisfaction	14.3 (3.2)	.08	.07	.11	.12	.20	-		
7. SPS	4.3 (.9)	.02	.03	-.02	-.05	-.30*	-.13	-	
8. Negative	.00 (.8)	.11	-.11	-.02	.12	-.31*	-.13	.22*	-
9. Positive	.00 (.9)	-.11	.12	.20*	-.01	-.02	-.01	-.02	-.63*

Note: Salary and Job Satisfaction had a smaller sample size (N = 223); Negative and Positive experiences represent standardised composite scores; * = Significant at $p < .01$ level.

Predicting Wellbeing

We first tested the independent and interactive effects of SPS and negative childhood experiences on wellbeing (Model 1). The model was significant overall, $F(5, 333) = 23.61$, $R^2 = .26$, $p < .001$. Gender predicted wellbeing, $\beta = .33$, $t = 3.59$, $p < .001$, as females showed lower wellbeing. Age did not predict wellbeing, $\beta = -.00$, $t = -.21$, $p = .835$. Increasing SPS predicted decreasing wellbeing, $\beta = -.18$, $t = -3.58$, $p < .001$. Increasing negative childhood experiences predicted decreasing wellbeing, $\beta = -.17$, $t = -3.47$, $p = .001$. The interaction between SPS and negative childhood experiences was significant, $\beta = -.23$, $t = -6.12$, $p < .001$ (see later RoS analyses).

We then tested the independent and interactive effects of SPS and positive childhood experiences on wellbeing (Model 2). The model was significant overall, $F(5, 333) = 12.38$, $R^2 = .16$, $p < .001$. Gender predicted wellbeing, $\beta = .43$, $t = 4.31$, $p < .001$, as females showed lower wellbeing. Age did not predict wellbeing, $\beta = -.00$, $t = -.41$, $p = .685$. Increasing SPS predicted decreasing wellbeing, $\beta = -.26$, $t = -5.21$, $p < .001$. Increasing positive childhood experiences did not predict wellbeing, $\beta = -.05$, $t = -.99$, $p = .321$. The interaction between SPS and positive childhood experiences was significant, $\beta = -.16$, $t = -3.41$, $p = .001$ (see later RoS analyses).

RoS Analyses

Model 1. RoS on Z revealed that the regression of negative experiences on wellbeing was significant for all values of SPS that fell outside the region -1.12 and -0.46. Plotted simple slopes at high SPS (+1 *SD*) revealed that increasing negative childhood experiences predicted decreasing wellbeing, $\beta = -.41$, $t = 8.68$, $p < .001$. Whereas, at low SPS (-1 *SD*), negative childhood experiences did not predict wellbeing, $\beta = .06$, $t = 1.44$, $p = .151$. RoS on X revealed that the regression of SPS on wellbeing was significant for all values of negative

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experiences that fell outside the region -1.13 and -0.47. The crossover point on negative experiences was -0.75 and the PA index was 0.77, therefore there was skew for the differential effects to be at the positive end of the spectrum (i.e., greater negative childhood experiences). These results reflected a crossover interaction, supporting differential susceptibility, as high SPS individuals showed extreme outcomes at both high and low levels of negative experiences, although effects were stronger in response to extreme negative experiences (**Figure 1**, left).

Model 2. RoS on Z revealed that the regression of positive experiences on wellbeing was significant for all values of SPS that fell outside the region -1.24 and 0.39. Plotted simple slopes at high SPS (+1 *SD*) revealed that increasing positive childhood experiences predicted decreasing wellbeing, $\beta = -.21$, $t = 2.95$, $p = .003$. Whereas, at low SPS (-1 *SD*), positive childhood experiences did not predict wellbeing, $\beta = .11$, $t = 1.60$, $p = .110$. RoS on X revealed that the regression of SPS on wellbeing was significant for all values of positive experiences that fell outside the region -3.74 and -0.84. The crossover point on positive experiences was -1.63 and the PA index was 0.95, therefore there were no differential effects. Low SPS individuals showed no benefit from positive experiences, while high SPS individuals showed negative effects in terms of decreasing wellbeing (**Figure 1**, right).

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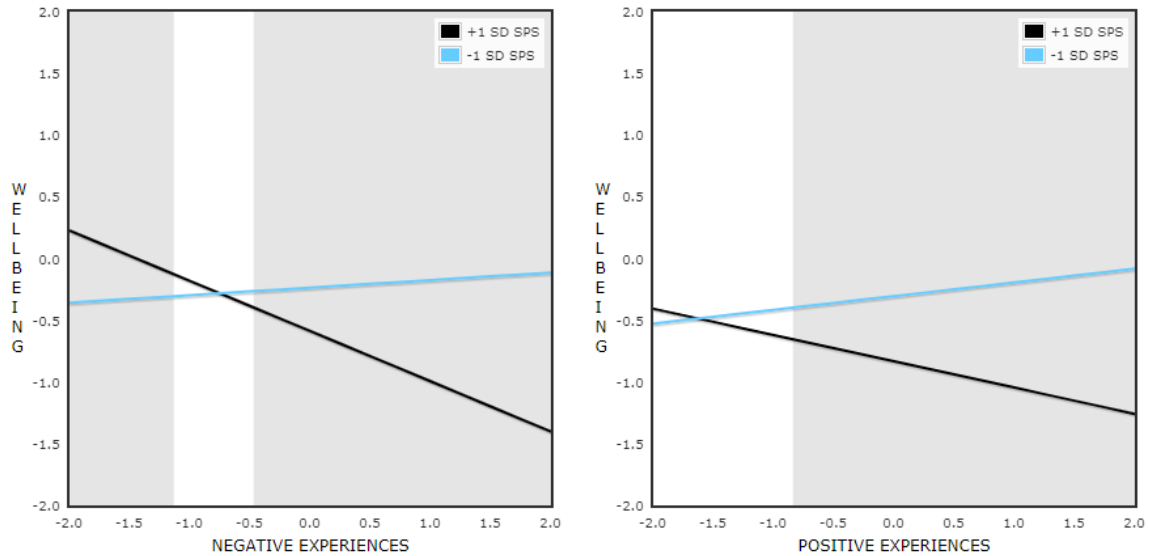


Figure 1. *Interactive effects for Model 1; Negative childhood experiences at high SPS (+1 SD) and low SPS (-1 SD) predicting wellbeing (left) and for Model 2; Positive childhood experiences at high SPS (+1 SD) and low SPS (-1 SD) predicting wellbeing (right). Grey area denotes Regions of Significance (RoS) on X.*

Supplementary Analyses

Some supplementary analyses were conducted to explore these findings further, by examining each of the SPS factors (i.e., EOE, LST, and AES), as well as each of the wellbeing subscales (i.e., emotional, psychological, and social), and finally by residualizing SPS scores for the shared variance with both negative childhood experiences and wellbeing (see Appendix C – pp. 58-67).

Predicting Job Satisfaction

Two further regression models were conducted. Model 3 tested the effect of negative childhood experiences and SPS on job satisfaction and was not significant overall, $F(5, 217) = 2.09$, $R^2 = .05$, $p = .068$. None of the predictors were significant. Model 4 tested the effect

of positive childhood experiences and SPS on job satisfaction and was not significant, $F(5, 217) = 1.26$, $R^2 = .03$, $p = .282$. None of the predictors were significant.

Discussion

The current study assessed the independent and interactive effects of retrospective childhood experiences and SPS on current wellbeing and job satisfaction. Model 1 found that negative childhood experiences predicted lower levels of wellbeing, high SPS predicted lower levels of wellbeing, and that there was an interaction between negative experiences and SPS. A crossover interaction was found, as high SPS individuals displayed the best and worst outcomes in response to the absence and presence of negative childhood experiences, consistent with differential susceptibility. Model 2 found that positive childhood experiences had no effect on wellbeing, high SPS predicted lower levels of wellbeing, and that there was an interaction between positive childhood experiences and SPS. The interaction did not significantly crossover, yet positive experiences did not predict wellbeing for low SPS individuals, whereas increasing positive experiences predicted decreasing wellbeing for high SPS individuals, which was unexpected. Model 3 and Model 4 found that neither childhood experiences, SPS, nor their interaction predicted any variance in job satisfaction, which failed to support our third and fourth hypotheses.

Differential susceptibility effects were found when assessing the interaction between SPS and negative childhood experiences on wellbeing. Not only were high SPS individuals more sensitive to negative childhood experiences, as evidenced by a stronger effect of negative experiences on wellbeing, they showed ‘for better and for worse’ outcomes, as wellbeing was significantly higher in the absence of negative experiences and significantly lower in the presence of negative experiences. This finding supports high SPS as a plasticity

factor, extending our previous findings, which suggested that high SPS was only a risk factor predicting low wellbeing (Booth et al., 2015). This new finding could be explained by the fact that negative and positive experiences were examined separately in the current study, as well as the use of RoS analysis, which is considered a better test of differential susceptibility than simple slopes analysis (Roisman et al., 2012). However, the PA index showed that the differential effect was greater at the positive end of the continuum (i.e., greater negative experiences), indicating that high SPS individuals may be particularly sensitive to increasing negative experiences. Further, they did not show the expected effect of positive childhood experiences on wellbeing, as increasing positive experiences predicted a slight decrease in wellbeing for high SPS individuals, which was unexpected. Therefore, these results should be replicated before drawing any firm conclusions.

Overall the effect of positive childhood experiences on wellbeing was not significant, which suggests that our measure of positive experiences was not adequate to predict wellbeing. Research on positive childhood experiences is lacking, which led us to develop the *Adapted Risky Families Questionnaire* for the current study. It is possible that our measure assessed fairly normative events, which do not have lasting effects on wellbeing. Future research should investigate particular positive experiences that have lasting effects, using longitudinal research designs. We did find an interaction between SPS and positive childhood experiences, as at low SPS, positive experiences did not predict wellbeing, while at high SPS positive experiences predicted a slight decrease in wellbeing. This could mean that any type of affective experience, be that positive or negative, has a deleterious effect on high SPS individuals. However, this should be interpreted with caution, as positive experiences had no effect on wellbeing overall, which was unexpected. Further, in our supplementary analysis, which controlled SPS for the effect of wellbeing, the regression lines

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became non-significant, suggesting that the shared variance between SPS and wellbeing was driving this effect. Regardless, this effect should be followed up in future research.

Some supplementary analyses were conducted to investigate the findings further. Firstly, the regression models were assessed for each of the SPS factors (i.e., EOE, LST, and AES). The results remained the same for each of the factors, suggesting that environmental sensitivity is observed for each of the factors. Then the models were re-analysed for each wellbeing subscale (i.e., emotional, psychological, and social). The social subscale performed differently to the others. In terms of negative childhood experiences, differential susceptibility was observed for emotional and psychological wellbeing, but social wellbeing reflected diathesis-stress. This could have been explained by the strong main effect relationship between SPS and social wellbeing, as high SPS individuals reported the lowest levels of social wellbeing. In terms of positive childhood experiences, the unexpected finding, which showed that at high SPS increasing positive experiences predicted decreasing wellbeing, was only observed for social wellbeing. One potential interpretation of this finding is that high SPS individuals with poor social functioning relied more heavily on family support during their development, therefore increasing family support predicted worse social wellbeing in high SPS adults. This suggests that future models should investigate the wellbeing subscales separately. Finally, the models were run using the SPS score residualised for the effect of negative childhood experiences and wellbeing, as these factors correlated with SPS. The results did not change using the SPS scores residualised for negative childhood experiences, but did change for the SPS score residualised for wellbeing. The differential effects disappeared at the positive end of the continuum (i.e., in combination with extreme negative and positive experiences), but remained significant at the negative end of the continuum (i.e., in the absence of negative and positive experiences). It appeared that high SPS individuals reported higher levels of wellbeing compared to low SPS individuals, as well

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as showing greater sensitivity (i.e., steeper regression lines), although the regression lines were non-significant in the case of positive childhood experiences. Future research should consider residualising SPS scores for another factor, such as neuroticism, so that not too much variance is taken out, due to residualising with the outcome of interest.

Differential susceptibility effects have proven difficult to support in adult phenotypic traits, whereas they are often found in studies of child temperament (Belsky & Pluess, 2009; Slagt et al., 2016). A recent meta-analysis found that childhood negative emotionality was a plasticity trait predicting differential susceptibility effects in childhood adjustment outcomes, but only when negative emotionality was assessed in infancy, as opposed to later childhood (Slagt et al., 2016). This suggests that phenotypic plasticity may only be observed in the early years and that the influence of supportive parenting throughout a child's life may shape the phenotypic trajectory towards less heightened sensitivity, or at least less observable sensitivity using currently available phenotypic measures. This is supported by the fact that SPS was positively correlated with negative childhood experiences in the current study, suggesting that high SPS individuals experienced more negative events in their childhood. Thus, individuals with the same degree of SPS in childhood who experienced supportive environments may report lower levels of SPS in adulthood. According to this proposition, adult SPS should be treated as an outcome in itself, reflecting elements of negative affect. Previous research has highlighted the influence of childhood trauma on personality, e.g., trauma predicts higher behavioural inhibition (Miu, Bîlc, Bunea, & Szentágotai-Tătar, 2017). Future research may investigate this hypothesis further, by assessing the development of SPS as a phenotype, using longitudinal designs.

Model 3 and Model 4 tested the effect of positive and negative childhood experiences and SPS on job satisfaction, and neither model included any significant predictor. This

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suggests that childhood experiences within the family, has no effect on later job satisfaction and neither does SPS. However, the current study may not have been powered enough to find such effects, as it used retrospective measures, which are not as powerful as prospective longitudinal measures. Thus, future research may find an association between childhood experiences and future job satisfaction. For example, a recent longitudinal study found that early maternal sensitivity predicted greater social and academic outcomes during adolescence and later adulthood (Raby, Roisman, Fraley, & Simpson, 2015).

The current study should be considered in light of its limitations. Due to the cross-sectional nature of study, we are unable to draw conclusions on the direction of effects. For example, we cannot be sure that negative childhood experiences predicted lower levels of wellbeing, as it is also possible that individuals experiencing low wellbeing reported more negative experiences. Further, the retrospective assessment of childhood experiences is problematic, because it relies on the memory of the individual, therefore cannot be considered an objective measure. Finally, while the current study suggests that SPS moderates the impact of childhood experiences on wellbeing, it is unclear whether current stress would have the same effect, which would be an interesting avenue for future research.

Future research would benefit from using prospective longitudinal designs, as well as multiple informants, in order to assess moderation of the environment from a life course perspective. Alternatively, experimental designs, which manipulate the environment in both a positive and negative direction, would provide a more objective test of differential susceptibility. Future research could also utilise naturally occurring positive and negative events, e.g., assessing differential responsivity to a natural disaster situation.

In conclusion, we found evidence supporting high SPS as a plasticity trait, as these individuals showed ‘for better and for worse’ outcomes in terms of wellbeing in response to

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the presence and absence of negative childhood experiences. However, we did not find increased responsivity to positive childhood experiences, which may have been related to suboptimal measurement of positive childhood experiences, in terms of its utility for predicting wellbeing. Future research should attempt to replicate the associations found in the current study. Further, more research is needed into specific positive experiences that influence wellbeing in the long term, as well as employing experimental and longitudinal research designs in order to investigate the direction of effects.

Appendix A: Psychometric properties for the Adapted Risky Families Questionnaire

Table 1. *The Adapted Risky Families Questionnaire (ARFQ)*

-
- 1) How often did a parent or other adult in the household make you feel that you were loved, supported, and cared for?
 - 2) How often did a parent or other adult in the household swear at you, insult you, put you down, or act in a way that made you feel threatened?
 - 3) How often did a parent or other adult in the household express physical affection for you, such as hugging, or other physical gestures of warmth and affection?
 - 4) How often did a parent or other adult in the household push, grab, shove, or slap you?
 - 5) Would you say that the household you grew up in was well-organized and well-managed?
 - 6) In your childhood, did you live with anyone who was a problem drinker or alcoholic, or who used street drugs?
 - 7) How often did a parent or other adult in the household ask you about any problems you were experiencing and offer guidance or support?*
 - 8) How often would you say that a parent or other adult in the household behaved violently toward a family member or visitor in your home?
 - 9) During your childhood did your parents go out of their way to help you, for example driving you to sports matches?*
 - 10) How often would you say there was quarrelling, arguing, or shouting between your parents?
 - 11) How often would you say there was quarrelling, arguing, or shouting between a parent and one of your siblings?
 - 12) How often would your parents be concerned with your whereabouts when you were away from home?*
 - 13) On the whole did you feel close with your parents during your childhood, in a way that you could go to them for help?*
 - 14) Would you say the household you grew up in was chaotic and disorganized?
 - 15) How often did you do positive activities together as a family, like eating meals together, or going on trips?*
 - 16) How often would you say you were neglected while you were growing up, that is, left on your own to fend for yourself?

Note: * Indicates new (positive) item.

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Table 2. *Factor loadings & communalities based on principal components analysis with Varimax rotation for 16 items from the ARFQ (N = 339)*

<i>Item</i>		Pos.	Neg.	Comm.
13	On the whole did you feel close with your parents during your childhood, in a way that you could go to them for help?*	.83		.75
1	How often did a parent or other adult in the household make you feel that you were loved, supported, and cared for?	.83		.71
7	How often did a parent or other adult in the household ask you about any problems you were experiencing and offer guidance or support?*	.81		.70
3	How often did a parent or other adult in the household express physical affection for you, such as hugging, or other physical gestures of warmth and affection?	.81		.64
9	During your childhood did your parents go out of their way to help you, for example driving you to sports matches?*	.72		.61
15	How often did you do positive activities together as a family, like eating meals together, or going on trips?*	.71		.61
5	Would you say that the household you grew up in was well-organized and well-managed?	.61		.71
8	How often would you say that a parent or other adult in the household behaved violently toward a family member or visitor in your home?		.81	.71
14	Would you say the household you grew up in was chaotic and disorganized?		.75	.71
10	How often would you say there was quarrelling, arguing, or shouting between your parents?		.73	.61
6	In your childhood, did you live with anyone who was a problem drinker or alcoholic, or who used street drugs?		.71	.53
4	How often did a parent or other adult in the household push, grab, shove, or slap you?		.71	.63
2	How often did a parent or other adult in the household swear at you, insult you, put you down, or act in a way that made you feel threatened?		.60	.71
11	How often would you say there was quarrelling, arguing, or shouting between a parent and one of your siblings?		.60	.41
16	How often would you say you were neglected while you were growing up, that is, left on your own to fend for yourself?		.60	.54

Note: *Pos.* = Positive factor, *Neg.* = Negative factor; *Comm.* = Communality; * Indicates new positive item; Factor loadings < .4 are suppressed; Item 12 excluded.

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Table 3. *Descriptive statistics for the two ARFQ factors (N = 339)*

	<i>No. of items</i>	<i>M (SD)</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>Cronbach's α</i>
Positive	7	3.71 (.95)	-.60	-.52	.91
Negative	8	2.13 (.88)	1.10	.66	.90

Note: *Item 12 was dropped for failing to load onto one of the factors.*

Key points (Appendix A)

- Five new positive items were added to the scale (Table 1).
- A Principal Components Analysis (PCA) found a clear two factor structure corresponding to *Positive experiences* and *Negative experiences* (Table 2). Positive experiences clustered together and negative experiences clustered together, suggesting that the absence of negative events does not equate to a positive environment.
- The PCA showed high communality for all items in the scale, suggesting that the ARFQ is an adequate measure of childhood experiences, however some negative items showed less communality, e.g., item 11 (“How often would you say there was quarrelling, arguing, or shouting between a parent and one of your siblings?”), which may have displayed uncommon variance due to the item requiring third person perspective, as opposed to evaluating personal experiences.
- One of the new positive items – “How often would your parents be concerned with your whereabouts when you were away from home?” – did not load sufficiently onto any factor and decreased the reliability (Cronbach’s α) of the positive subscale, therefore was not included in further analyses.
- Table 3 shows the descriptive statistics for the subscales, which both showed excellent internal consistency (Cronbach’s $\alpha > .90$).

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Appendix B: Psychometric properties for the Maternal-Paternal Warmth vs Coercive Parenting Scales (M-P-WCP)

Table 1. *Factor loadings & communalities based on principal components analysis with Varimax rotation for 16 items from the M-P-WCP Father scale (N = 328)*

<i>Item</i>	<i>Coercive</i>	<i>Warm</i>	<i>Cold</i>	<i>Comm.</i>
1 Swore at me	.81			.72
2 Insulted me or put me down	.81			.81
3 Acted in a way that made me afraid and that I might be physically hurt	.86			.81
4 Pushed, grabbed, or slapped me	.85			.75
5 Spoke to me in a warm and friendly voice		.70		.60
8 Appeared to understand my problems and worries		.73		.64
9 Was affectionate to me		.82		.72
10 Enjoyed talking things over with me		.81		.68
11 Frequently smiled at me		.76		.63
13 Made me feel I was wanted		.71		.70
14 Could make me feel better when I was upset		.71		.61
6 Did not help me as much as I needed			.64	.60
7 Seemed emotionally cold to me			.60	.60
12 Did not seem to understand what I needed or wanted			.73	.70
15 Did not talk with me very much			.81	.71
16 Did not praise me			.72	.65

Note: *Comm. = Communality; All items loaded > .4; 11 participants reported a missing father growing up.*

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Table 2. *Factor loadings & communalities based on principal components analysis with Varimax rotation for 16 items from the M-P-WCP Mother scale (N = 335)*

<i>Item</i>	<i>Coercive</i>	<i>Warm</i>	<i>Cold</i>	<i>Comm.</i>
1 Swore at me	.81			.72
2 Insulted me or put me down	.63			.70
3 Acted in a way that made me afraid and that I might be physically hurt	.84			.81
4 Pushed, grabbed, or slapped me	.91			.81
5 Spoke to me in a warm and friendly voice		.73		.60
8 Appeared to understand my problems and worries		.81		.64
9 Was affectionate to me		.82		.71
10 Enjoyed talking things over with me		.80		.75
11 Frequently smiled at me		.81		.71
13 Made me feel I was wanted		.80		.81
14 Could make me feel better when I was upset		.81		.66
6 Did not help me as much as I needed			.81	.72
7 Seemed emotionally cold to me			.61	.61
12 Did not seem to understand what I needed or wanted			.75	.68
15 Did not talk with me very much			.81	.72
16 Did not praise me			.73	.71

Note: *Comm.* = *Communality*; All items loaded > .4; 4 participants reported a missing mother growing up.

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Table 3. *Descriptive statistics for the three M-P-WCP factors by Father and Mother*

<i>Scale</i>	<i>Factor</i>	<i>No. of items</i>	<i>M (SD)</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>Cronbach's α</i>
Father	Coercive	4	1.71 (.86)	1.20	.38	.91
	Warm	7	2.92 (.82)	-.61	-.51	.90
	Cold	5	2.31 (.88)	.20	-.98	.85
Mother	Coercive	4	1.60 (.79)	1.57	1.54	.90
	Warm	7	3.31 (.78)	-1.31	.99	.92
	Cold	5	1.85 (.84)	.85	-.16	.90

Key points (Appendix B)

- Principal components analysis for both Father (Table 1) and Mother (Table 2) scales from the 16-item M-P-WCP scales found the same three factor structure corresponding to *Coercive parenting*, *Warm parenting* and *Cold parenting*.
- All items showed high communality for the total scale.
- Descriptive statistics for the subscales are presented in Table 3. All subscales showed good internal consistency (Cronbach's $\alpha > .85$).

Appendix C

Supplementary Sensitivity Analyses

SPS factors

Descriptive statistics and correlations

We analysed the models predicting wellbeing again using each of the factors of SPS (i.e., EOE, LST, and AES). **Table 1** presents the descriptive statistics and correlations for the relevant variables. EOE and LST were highly inter-correlated, while AES showed only small correlations with the other factors. All of the SPS factors showed a negative correlation with wellbeing, but LST showed the strongest effect. Similarly, all of the factors showed a marginal positive correlation with negative childhood experiences, although LST showed the strongest relationship.

Table 1. *Descriptive statistics and correlations between factors of SPS and relevant variables*

Variable	Mean (SD)	1	2	3	4	5	6
1. SPS	4.28 (.9)	-					
2. EOE	4.36 (1.3)	.80*	-				
3. LST	3.75 (1.3)	.84*	.56*	-			
4. AES	4.74 (1.0)	.57*	.15*	.24*	-		
5. Negative	.00 (.8)	.21*	.14*	.21*	.12*	-	
6. Positive	.00 (.9)	-.02	-.00	-.05	.02	-.63*	-
7. Wellbeing	147.94 (17.1)	-.27*	-.14*	-.27*	-.21*	-.31*	-.01

Note: SPS = Sensory-Processing Sensitivity; EOE = Ease of Excitation; LST = Low Sensory Threshold; AES = Aesthetic Sensitivity; *Significant at $p < .01$ level.

Regression models

Table 2 presents the results from the regression models for each of the SPS factors and negative/positive childhood experiences predicting wellbeing. In all six models, the SPS factor was a risk factor for low wellbeing and interacted with childhood experiences.

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Table 2. Supplementary analyses showing regression models for SPS factors and childhood experiences predicting wellbeing ($N = 339$).

1) Negative experiences and EOE on wellbeing: $F(5,333) = 15.11, R^2 = .18, p < .001$				
	β	$SE \beta$	t	p
Constant	-.39	.21	-1.84	.065
Negative	-.22	.05	-4.33	.000
EOE	-.06	.05	-1.30	.194
Negative x EOE	-.19	.04	-4.43	.000
2) Negative experiences and LST on wellbeing: $F(5,333) = 24.68, R^2 = .27, p < .001$				
	β	$SE \beta$	t	p
Constant	-.51	.20	-2.52	.012
Negative	-.15	.05	-3.02	.003
LST	-.23	.04	-4.86	.000
Negative x LST	-.27	.04	-6.37	.000
3) Negative experiences and AES on wellbeing: $F(5,333) = 24.68, R^2 = .27, p < .001$				
	β	$SE \beta$	t	p
Constant	-.48	.20	-2.34	.020
Negative	-.23	.04	-4.93	.000
AES	-.15	.04	-3.16	.002
Negative x AES	-.24	.04	-5.77	.000
4) Positive experiences and EOE on wellbeing: $F(5,333) = 6.56, R^2 = .09, p < .001$				
	β	$SE \beta$	t	p
Constant	-.52	.22	-2.32	.021
Positive	-.05	.05	-0.97	.329
EOE	-.13	.05	-2.57	.011
Positive x EOE	-.14	.05	-2.80	.005
5) Positive experiences and LST on wellbeing: $F(5,333) = 11.72, R^2 = .15, p < .001$				
	β	$SE \beta$	t	p
Constant	-.62	.21	-2.86	.004
Positive	-.05	.05	-1.05	.292
LST	-.27	.05	-5.44	.000
Positive x LST	-.12	.04	-2.52	.012
6) Positive experiences and AES on wellbeing: $F(5,333) = 7.69, R^2 = .10, p < .001$				
	β	$SE \beta$	t	p
Constant	-.55	.22	-2.45	.015
Positive	-.04	.05	-0.81	.415
AES	-.18	.05	-3.55	.000
Positive x AES	-.12	.05	-2.34	.020

Note: EOE = Ease of Excitation; LST = Low Sensory Threshold; AES = Aesthetic Sensitivity; Gender and age were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance.

Figure 1 presents the Regions of Significance (RoS) results, which were conducted to follow up these interactions. In the case of negative experiences, high SPS levels on each factor

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predicted differential susceptibility effects, as high SPS individuals showed the best and worst outcomes relative to the absence and presence of negative childhood experiences. In terms of positive experiences, high SPS individuals showed worsening wellbeing in combination with increasing levels of positive childhood experiences. In all of the models, low SPS individuals showed environmental resistance, indicated by non-significant regression lines.

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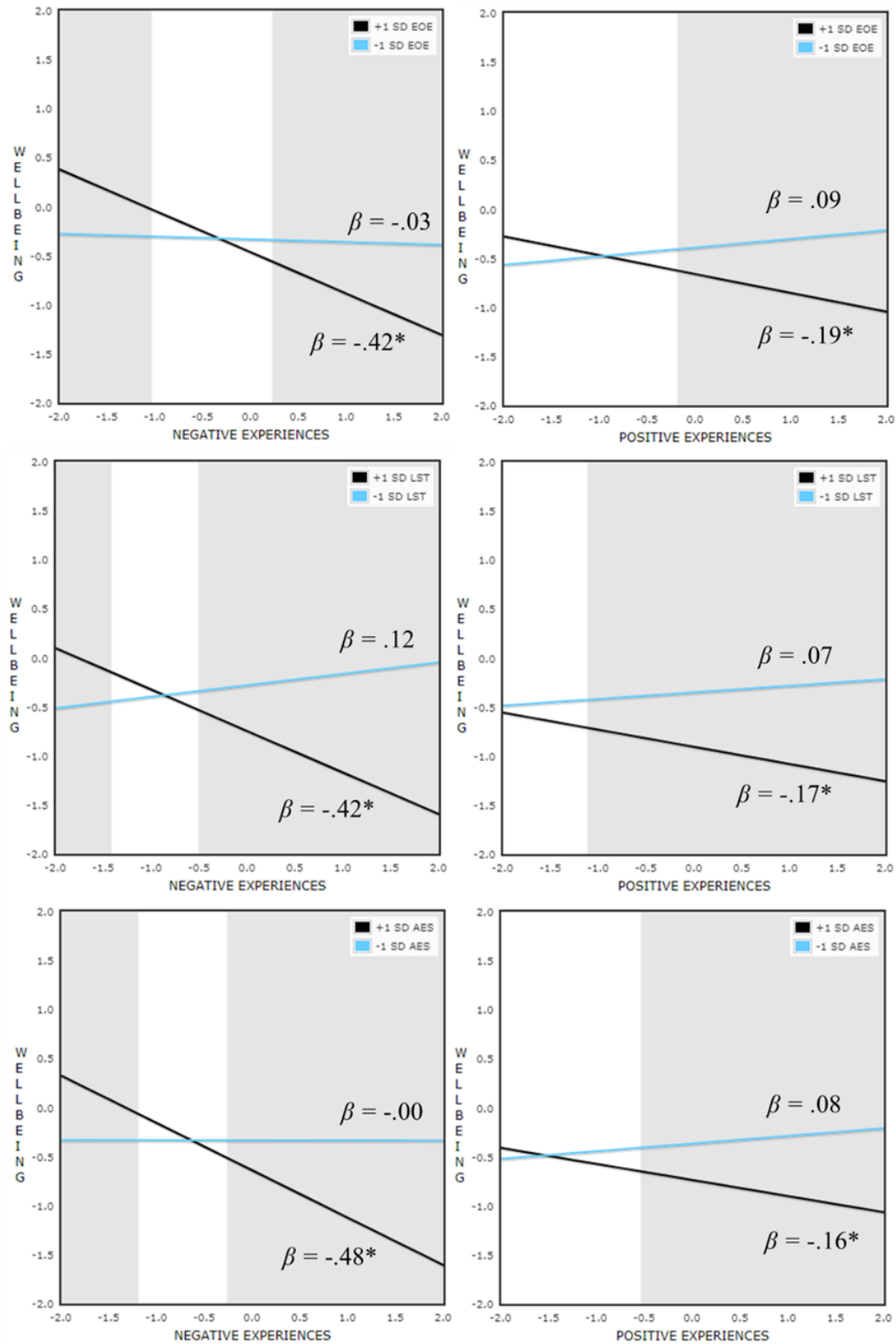


Figure 1. Supplementary analyses showing Regions of Significance (RoS) for all interactions between the separate SPS factors (i.e., EOE, LST, and AES) and negative childhood experiences predicting wellbeing (left column) and the separate SPS factors and positive childhood experiences predicting wellbeing (right column); **Note:** Grey area denotes RoS on X; Slope depicted at high (+1 SD) and low (-1SD) for each factor; *Significant at the $p < .05$ level.

Wellbeing subscales

We then analysed the models using each of the wellbeing subscales as the outcome variable.

Table 3 presents the results from six regression models. A significant interaction was present in all cases, apart from between SPS and positive childhood experiences predicting emotional wellbeing, which was non-significant. Interactions were followed up with RoS analysis.

Figure 2 presents the interaction results. In the case of negative childhood experiences, the differential susceptibility, crossover interaction, was supported in models predicting emotional and psychological wellbeing, but not social wellbeing. This latter model reflected diathesis-stress, as high SPS showed worsening wellbeing in combination with increasing negative experiences, compared to low SPS, and no differential effects in the absence of negative experiences was observed. This may have been related to the fact that SPS showed the strongest main effect relationship with social wellbeing (i.e., high SPS showed lowest levels of social wellbeing). This suggests that high SPS is a particular risk factor for poor social wellbeing, in comparison to emotional and psychological wellbeing, which may obscure differential effects. In terms of positive childhood experiences, the interaction, which reflected increasing positive experiences predicting decreasing wellbeing at high SPS, was only found for social wellbeing. The regression lines were non-significant at high and low SPS in models of emotional and psychological wellbeing. Therefore, this unexpected finding was driven by low levels of social wellbeing observed in high SPS individuals. One potential interpretation of this finding is that high SPS individuals with poor social functioning relied more heavily on family support during their development, therefore increasing family support predicted worse social wellbeing in high SPS individuals.

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Table 3. Supplementary analyses showing regression models for SPS and negative/positive childhood experiences predicting each wellbeing subscale (N = 339).

1) Negative x SPS on emotional wellbeing: $F(5,333) = 3.36, R^2 = .04, p = .006$				
	β	SE β	t	p
Constant	-.09	.23	-0.42	.671
Negative	.01	.05	0.31	.754
SPS	.11	.05	2.06	.039
Negative x SPS	-.15	.04	-3.62	.000
2) Negative x SPS on psychological wellbeing: $F(5,333) = 17.19, R^2 = .20, p < .001$				
	β	SE β	t	p
Constant	-.32	.21	-1.54	.124
Negative	-.19	.05	-3.75	.000
SPS	-.08	.05	-1.74	.082
Negative x SPS	-.19	.03	-5.02	.000
3) Negative x SPS on social wellbeing: $F(5,333) = 24.68, R^2 = .27, p < .001$				
	β	SE β	t	p
Constant	-.38	.21	-1.82	.068
Negative	-.12	.05	-2.36	.019
SPS	-.27	.05	-5.53	.000
Negative x SPS	-.17	.03	-4.37	.000
4) Positive x SPS on emotional wellbeing: $F(5,333) = 1.50, R^2 = .02, p = .189$				
	β	SE β	t	p
Constant	-.20	.23	-0.85	.393
Positive	-.10	.05	-1.86	.064
SPS	.07	.05	1.42	.155
Positive x SPS	-.04	.05	-0.81	.414
5) Positive x SPS on psychological wellbeing: $F(5,333) = 7.54, R^2 = .10, p < .001$				
	β	SE β	t	p
Constant	-.46	.22	-2.05	.041
Positive	.00	.05	0.01	.988
SPS	-.17	.05	-3.34	.001
Positive x SPS	-.11	.04	-2.30	.022
6) Positive x SPS on social wellbeing: $F(5,333) = 14.71, R^2 = .18, p < .001$				
	β	SE β	t	p
Constant	-.50	.21	-2.34	.020
Positive	-.06	.05	-1.19	.232
SPS	-.33	.05	-6.78	.000
Positive x SPS	-.16	.04	-3.61	.000

Note: SPS = Sensory Processing Sensitivity; Gender and age were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance.

2. SPS & Life Outcomes

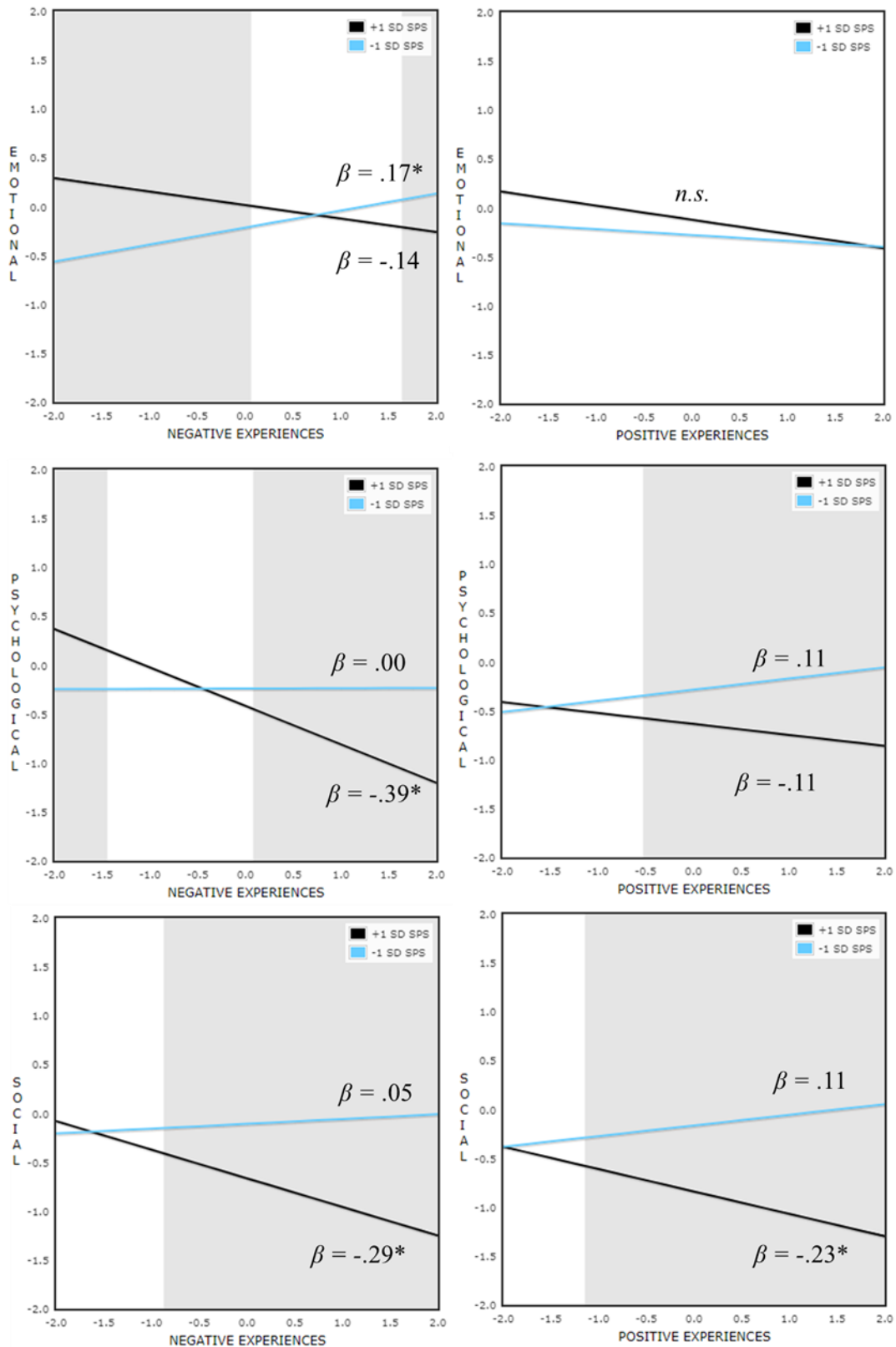


Figure 2. Regions of Significance (RoS) for interaction between SPS and negative (left) and positive (right) childhood experiences predicting emotional wellbeing (top), psychological wellbeing (middle), and social wellbeing (bottom); **Note:** Grey area denotes RoS on X; Slope depicted at high (+1 SD) and low (-1SD) SPS; *Significant at the $p < .05$ level.

SPS residualised scores

Further analyses were conducted by calculating a residualised score for SPS by controlling for the effect of negative childhood experiences and for wellbeing, as both these factors correlated with SPS, therefore shared variance. **Table 4** presents the results from regression analyses for these two new SPS residualised factors and negative/positive childhood experiences predicting wellbeing. When SPS was controlled for negative experiences, the results remained the same. However, when SPS was controlled for wellbeing, it no longer predicted wellbeing outcomes. Interactions between SPS (residualised) and childhood experiences were significant in all cases and followed up with RoS analyses. **Figure 3** depicts the RoS analyses, which were unchanged when SPS was controlled for negative childhood experiences (top row). However, when SPS was controlled for wellbeing, increasing negative childhood experiences predicted decreasing wellbeing at high and low SPS, although effects were more extreme at high SPS. The differential effects disappeared, as the regression lines only differed at the negative end of the continuum (i.e., in the absence of negative childhood experiences). For positive experiences, the interaction was significant, although positive childhood experiences did not predict wellbeing at high or low SPS. The interaction was driven at the negative end of the continuum (i.e., in the absence of positive childhood experiences), where it appeared that high SPS reported higher levels of wellbeing. Together, these results suggest that when SPS is controlled for wellbeing, high SPS reflects heightened environmental sensitivity, in line with differential susceptibility, although interactive effects were small and were not significantly different at the positive end of the continuum. Controlling SPS for wellbeing removed variance in our models, which may have reduced the chance to support differential susceptibility. Future research should consider controlling SPS for neuroticism, which is a personality factor that predicts psychopathology (Jylha insert REF).

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Table 4. Supplementary analyses using SPS scores residualised for both negative childhood experiences and wellbeing respectively ($N = 339$)

1) Negative experiences and SPS (res:negative) on wellbeing: $F(5,333) = 21.54$, $R^2 = .24$, $p < .001$				
	β	$SE \beta$	t	p
Constant	-.47	.20	-2.31	.021
Negative	-.25	.04	-5.34	.000
SPS	-.18	.04	-3.74	.000
Negative x SPS	-.21	.03	-5.44	.000
2) Positive experiences and SPS (res:negative) on wellbeing: $F(5,333) = 9.00$, $R^2 = .11$, $p < .001$				
	β	$SE \beta$	t	p
Constant	-.55	.22	-2.47	.014
Positive	-.03	.05	-0.64	.521
SPS	-.21	.05	-4.14	.000
Positive x SPS	-.13	.04	-2.85	.005
3) Negative experiences and SPS (res:wellbeing) on wellbeing: $F(5,333) = 10.89$, $R^2 = .14$, $p < .001$				
	β	$SE \beta$	t	p
Constant	-.49	.22	-2.23	.026
Negative	-.27	.05	-5.20	.000
SPS	.03	.05	0.60	.544
Negative x SPS	-.10	.04	-2.13	.034
4) Positive experiences and SPS (res:wellbeing) on wellbeing: $F(5,333) = 4.77$, $R^2 = .06$, $p < .001$				
	β	$SE \beta$	t	p
Constant	-.54	.22	-2.37	.018
Positive	-.04	.05	-0.86	.389
SPS	-.02	.05	-0.38	.698
Positive x SPS	-.12	.05	-2.45	.014

Note: SPS = Sensory-Processing Sensitivity; SPS was residualised for the shared variance with both negative experiences and wellbeing prior to analysis; Age and Gender were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance.

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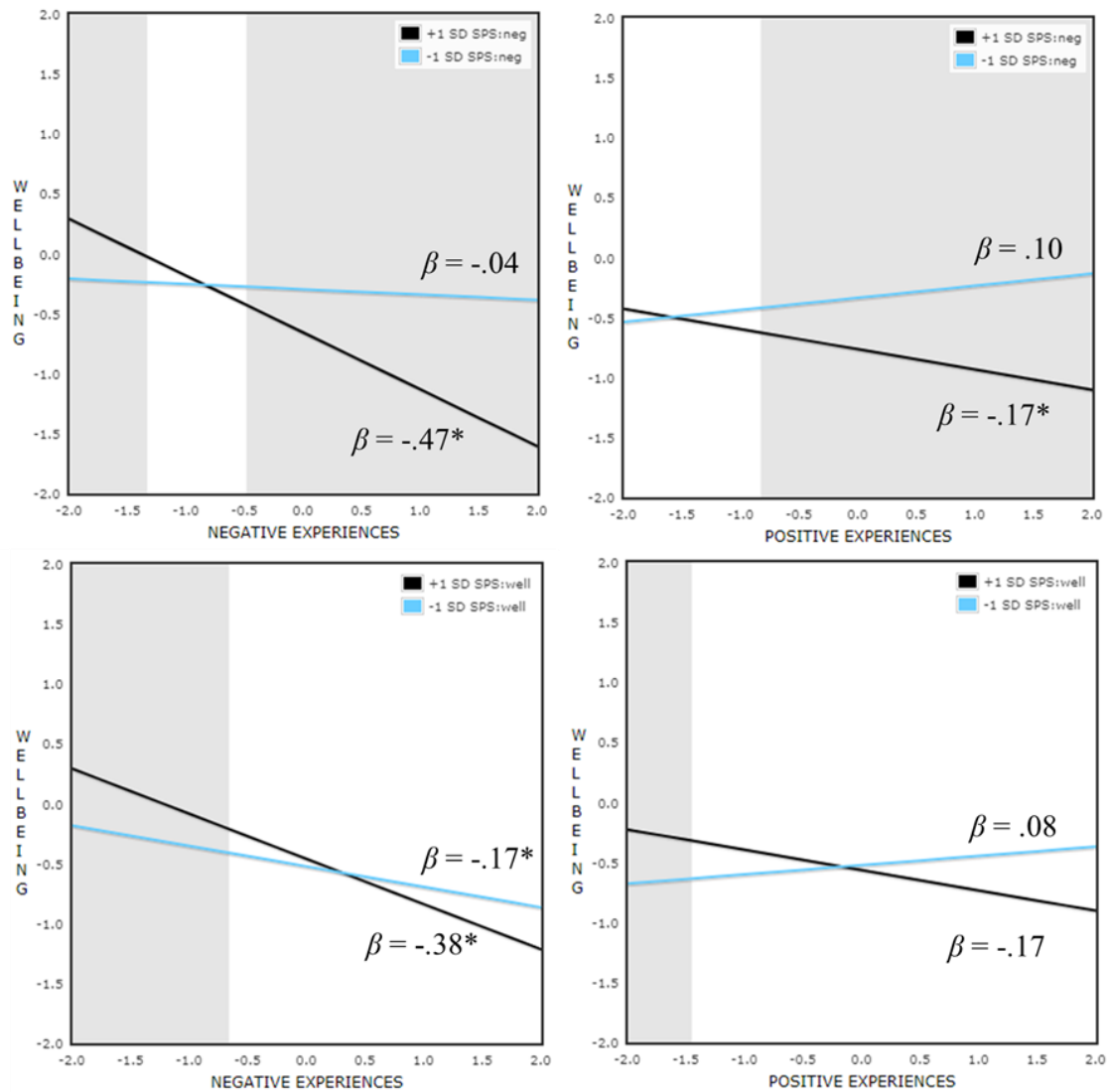


Figure 3. Supplementary analyses showing Regions of Significance (RoS) for all interactions between SPS scores residualised for negative experiences (top) and residualised for wellbeing (bottom). Interactions with negative experiences (left) and interactions with positive experiences (right); **Note:** Grey area denotes RoS; Slope depicted at high (+1 SD) and low (-1SD) for each factor; *Significant at the $p < .05$ level.

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Chapter 3

3

A Moderated Mediation model of Environmental Sensitivity: does Emotion Regulation mediate the link between experience and outcome?

Abstract: Previous research has indicated that Sensory-Processing Sensitivity (SPS) is a trait that moderates the impact of the environment on mental health outcomes, as high SPS individuals appear to be more environmentally sensitive. Caregiver experiences in childhood are important for shaping emotional development, as emotion regulation skills have been shown to mediate the pathway between early caregiver experiences and mental health outcomes. The aim of the current study was to integrate previous research and test whether SPS moderates the mediation effects of emotion regulation on early caregiver experiences, predicting wellbeing and depression in a healthy sample of adults ($N = 389$). Mediation effects were found, as emotion regulation either partially or fully mediated the pathways between positive and negative childhood experiences, predicting wellbeing and depression. Moderated-mediation was not supported, as SPS did not interact with positive or negative childhood experiences in these models. However, exploratory analyses were conducted, by combining data with *Chapter 2* (total $N = 727$), which supported moderation with regard to wellbeing. High SPS individuals were more sensitive to negative childhood experiences predicting low wellbeing, supporting a diathesis-stress model. Low SPS individuals were more sensitive to positive childhood experiences predicting high wellbeing, supporting a vantage sensitivity model. A post-hoc power analysis showed that only the combined total sample had enough power to detect interactive effects, highlighting the need for very large samples in studies of environmental moderation.

Introduction

Sensory-Processing Sensitivity (SPS) is a personality trait describing individual differences in environmental sensitivity. It is proposed that high SPS individuals are more sensitive to subtleties in the environment, engage deeper cognitive processing strategies, are more inhibited in novel situations and show heightened emotional reactivity (Aron & Aron, 1997; Jagiellowicz et al., 2011). SPS has been shown to correlate with various psychological outcomes, as high SPS is related to higher rates of anxiety and depression (Brindle, Moulding, Bakker, & Nedeljkovic, 2015; Liss et al., 2005), alexithymia and factors related to autism (Liss, Mailloux, & Erchull, 2008), lower life satisfaction (Booth et al., 2015) and difficulties in emotion regulation (Brindle et al., 2015). Yet, studies of environmental moderation have shown that psychopathological outcomes associated with SPS are often only apparent when high SPS individuals have experienced negative childhood experiences (Aron & Aron, 1997; Aron et al., 2005; Booth et al., 2015; Liss et al., 2005). These findings support high SPS as a marker of heightened environmental sensitivity (Pluess, 2015a) and suggest that high SPS individuals have a greater capacity to internalise situations and learn from the environment.

While SPS has been shown to moderate the environment on mental health outcomes, including lower life satisfaction and higher levels of depression (Booth et al., 2015; Liss et al., 2005), it has also been shown to moderate positive environmental experiences, typically in studies employing experimental designs (Lionetti et al., 2018; Pluess & Boniwell, 2015). This suggests that high SPS may represent a plasticity trait, supporting differential susceptibility (Belsky, 2005; Belsky & Pluess, 2009), as high SPS individuals have shown heightened responsivity to both positive and negative experiences. In *Chapter 2*, we found partial support for differential susceptibility, as high (relative to low) SPS individuals, displayed the highest and lowest levels of wellbeing relative to the absence or presence of

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negative childhood experiences. However, we did not find that high SPS individuals displayed heightened responsivity to positive childhood experiences, as differential susceptibility would predict. This may have been because our measure of positive childhood experiences was not sensitive enough to pick up variability in environmental responsivity, as it may reflect a measure of fairly normative developmental experiences. Nevertheless, these results require replication in a new sample, which was one of the aims of the current study. Besides testing this moderation effect again, the current study included a new mediator in the model - *Emotion Regulation* - in order to gain a better understanding of individual pathways to positive and negative mental health outcomes.

Emotion regulation describes “the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive temporal features, to accomplish one’s goals” (Thompson, 1994, p.27). It is crucial for adaptively navigating emotional situations in every aspect of life, including interpersonal and intrapersonal experiences. According to the model by Gratz and Roemer (2004), Difficulties in Emotion Regulation Skills (DERS) can be split into six separate factors, including (i) Non-acceptance (e.g., “When I’m upset I feel guilty for feeling that way”), (ii) Goals (e.g., “When I’m upset I have difficulty concentrating”), (iii) Impulse-control (e.g., “When I’m upset I lose control over my behaviours”), (iv) Awareness (e.g., “I am attentive to my feelings” – reverse scored), (v) Strategies (e.g., “When I’m upset, it takes me a long time to feel better”), and (vi) Clarity (e.g., “I am confused about how I feel”).

DERS are considered an antecedent to psychopathology, such as depression (Berking, Wirtz, Svaldi, & Hofmann, 2014; Berking et al., 2008; Burns, Jackson, & Harding, 2010). For example, using a longitudinal cross-lagged panel design, Berking et al. (2014) showed that DERS predicted depression severity five years later, whereas prior depression severity

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did not predict future DERS, suggesting that DERS are a causal and maintaining factor involved in depression. Further, DERS have been shown to fully mediate the link between childhood maltreatment and depression (Schierholz et al., 2016). Emotion regulation skills are thought to be learnt from interpersonal caregiver experiences, and DERS are thought to arise from harsh and unsupportive parenting practices, including criticism, punishment and emotional minimisation (Shipman et al., 2007). Emotional abuse in childhood has emerged as the best predictor of DERS over and above physical or sexual abuse (Burns et al., 2010). While the effects of negative childhood experiences on DERS have been established, it is unclear whether positive childhood experiences might also predict emotion regulation contributing to enhanced psychological wellbeing. We included DERS in our model, in order to firstly assess mediation of childhood experiences, as well as moderation of these effect by SPS.

To our knowledge, only one other study has assessed the association between SPS and DERS (Brindle et al., 2015). These authors tested whether DERS mediated the relationship between SPS and depression, as high SPS has consistently been associated with low mood. They supported partial mediation, by the subscales ‘Awareness’ and ‘Strategies’. The authors concluded that high SPS represents an inability to tolerate negative emotional states, which is a risk factor for the development of depression. However, these pathways were not straightforward, as high SPS was only positively correlated with some of the DERS subscales and actually showed a negative correlation with the ‘Awareness’ subscale, suggesting that high SPS individuals have better awareness of their emotions, which could be a protective factor. Given that emotion regulation skills are learnt from early caregiver experiences (Shipman et al., 2007), and high SPS individuals are expected to show heightened environmental sensitivity (Aron et al., 2012), we propose that childhood experiences should also be considered in the model. High (relative to low) SPS individuals

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may show better mental health in combination with positive childhood experiences, due to better skills in emotion regulation. Conversely, we would expect that high (relative to low) SPS individuals would show worse mental health in combination with negative childhood experiences, due to poor emotion regulation skills.

In the current study we tested four moderated mediation models of both positive and negative childhood experiences predicting both wellbeing and depression, mediated by DERS and moderated by SPS (**Figure 1**). This builds on *Chapter 2*, as we attempted to replicate the interaction between childhood experiences and SPS predicting wellbeing. The current study was different as we also assessed depression as an outcome, as this has previously been associated with DERS (Berking et al., 2014; Schierholz et al., 2016). We tested the indirect path between childhood experiences and our mental health outcomes mediated by DERS. We also tested the conditional paths relative to high and low SPS, in order to test for moderation. We expected that high SPS individuals would show extreme outcomes, particularly in the models of negative childhood experiences.

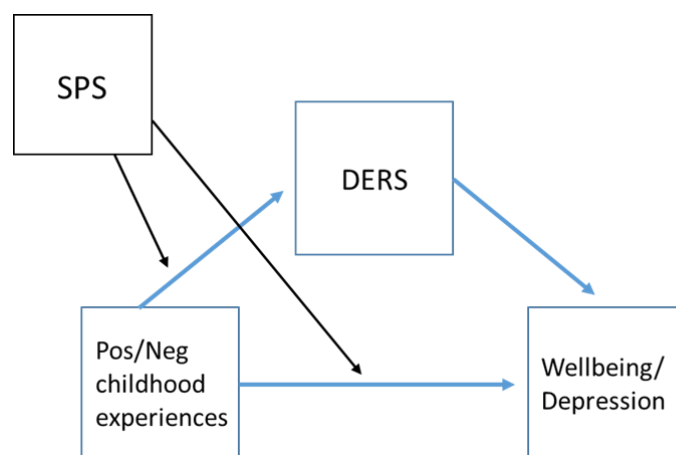


Figure 1. Moderated mediation model; DERS (M) mediates the effect of childhood experiences (X) on wellbeing outcomes (Y), and SPS (Z) moderates the effect of childhood experiences (X) on both DERS (M) and wellbeing (Y); Note: SPS = Sensory Processing Sensitivity, DERS = Difficulties in Emotion Regulation.

Hypotheses

1. Increasing negative childhood experiences will predict increasing depression, which will be mediated by DERS. SPS will moderate the pathway between negative childhood experiences on DERS and negative childhood experiences on depression, as the effects will be stronger in high SPS individuals.
2. Increasing negative childhood experiences will predict decreasing wellbeing, which will be mediated by DERS. SPS will moderate the pathway between negative childhood experiences on DERS and negative childhood experiences on wellbeing, as the effects will be stronger in high SPS individuals.
3. Increasing positive childhood experiences will predict decreasing depression, which will be mediated by DERS. SPS will moderate the pathway between positive childhood experiences on DERS and positive childhood experiences on depression, as the effects will be stronger in high SPS individuals.
4. Increasing positive childhood experiences will predict increasing wellbeing, which will be mediated by DERS. SPS will moderate the pathway between positive childhood experiences on DERS and positive childhood experiences on wellbeing, as the effects will be stronger in high SPS individuals.

Method

Participants

Participants were 389 individuals who were recruited from an online database called *Prolific Academic*. Participants who contributed data for *Chapter 2* were unable to take part. Participants were reimbursed £3.50 for taking part in the experiment, which involved completing the survey questions for the current chapter, as well as completing two cognitive

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tasks (see *Chapter 6*). The sample was aged between 18 and 55 (mean age = 34.38, $SD = 3.37$). The sample was 60% female and 40% male.

Measures

Demographics. Participants indicated their gender (male, female, other), their age in years (free text box) and their highest level of completed education (1 = “Secondary school”, 2 = “Vocational/technical school”, 3 = “Some college”, 4 = “Bachelor’s degree”, 5 = “Master’s degree”, 6 = “Doctoral degree”).

The Highly Sensitive Person Scale – Short Form (HSPS-SF) (Pluess et al., 2011). This was the same measure as described in *Chapter 2*. In the current study the scale showed good internal consistency (Cronbach’s $\alpha = .81$). We ran Principal Components Analysis (PCA) with Varimax rotation in order to assess the factor structure (Appendix A – pp. 100-101). The PCA found a clear three-factor solution which explained 61% of total variance. We found the exact same factor structure and item loadings as the original authors (Pluess et al., 2011). Five items loaded onto Ease of Excitation (EOE, e.g., “Do you find it unpleasant to have a lot going on at once?”), four items loaded onto Aesthetic Sensitivity (AES, e.g., “Are you deeply moved by the arts or music?”) and three items loaded onto Low Sensory Threshold (LST, e.g., “Are you made uncomfortable by loud noises?”). EOE showed good internal consistency (Cronbach’s $\alpha = .87$), while AES and LST showed adequate internal consistency (Cronbach’s $\alpha = .70$ for both).

The Difficulties in Emotion Regulation Scale (DERS) (Gratz & Roemer, 2004). The DERS is a 36-item scale designed to measure emotion regulation difficulties. It consists of 6 separate factors, including ‘Non-acceptance of emotional responses’ (Non-Accept) (e.g., “When I’m upset, I feel guilty for feeling that way”), ‘Difficulties engaging in goal-direction’ (Goals) (e.g., “When I’m upset, I have difficulty concentrating”), ‘Impulse control difficulties’

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(Impulse) (e.g., “When I’m upset, I feel out of control”), ‘Lack of emotional awareness’ (Aware) (e.g., “I am attentive to my feelings” reverse-scored), ‘Limited access to emotion regulation strategies’ (Strategies) (e.g., “When I’m upset, it takes me a long time to feel better”) and ‘Lack of emotional clarity’ (Clarity) (e.g., “I have difficulty making sense of my feelings”). Participants were asked to rate each item using a 5-point scale from 1 (“Almost never”) to 5 (“Almost always”). A DERS total score and a score for each separate factor was calculated by averaging the items. Internal consistency for the total score was excellent (Cronbach’s $\alpha = .94$). As for the subscales, internal consistency was excellent for ‘Non-accept’ (Cronbach’s $\alpha = .92$), good for ‘Goals’ (Cronbach’s $\alpha = .87$), good for ‘Impulse’ (Cronbach’s $\alpha = .84$), good for ‘Aware’ (Cronbach’s $\alpha = .83$), excellent for ‘Strategies’ (Cronbach’s $\alpha = .91$) and adequate for ‘Clarity’ (Cronbach’s $\alpha = .80$).

The Adapted Risky Families Questionnaire (ARFQ). The ARFQ was developed for *Chapter 2* to assess positive and negative childhood experiences. In *Chapter 2* we added 5 more positive experiences to attempt to balance the measure with regard to positive and negative experiences. We conducted PCA which found a clear two-factor structure for positive and negative experiences. One of the new items (“How often would your parents be concerned with your whereabouts when you were away from home?”) did not load onto any factor and was dropped. For the current study we replaced this with another item (“How often did you see your parents expressing emotional support and affection for one another?”), which was designed to match one of the negative items (“How often would you say there was quarrelling, arguing or shouting between your parents?”). Once again, we ran PCA on the ARFQ (Appendix B – pp. 102-103). The PCA found a clear two-factor structure, which explained 60% of the total variance. All of the positive items loaded onto one factor and all of the negative items loaded onto a second factor. The positive subscale showed excellent

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internal consistency (Cronbach's $\alpha = .91$) and the negative subscale showed good internal consistency (Cronbach's $\alpha = .87$).

The Mental Health Continuum – Short Form (MHC-SF) (Keyes, 2009). The MHC-SF is a 14-item scale derived from the longer 40-item version (Keyes, 2002). Participants were asked to rate how they have been feeling during the past month (e.g., “happy”, “interested in life”, “that you had warm and trusting relationships with others”) using a 6-point scale from 0 (“Never”) to 6 (“Every day”). The MHC-SF has been shown to be a reliable and relatively stable measure of wellbeing (Keyes, 2009). A mean score of the items was calculated to generate a score for wellbeing. The scale showed excellent internal consistency (Cronbach's $\alpha = .94$).

The Patient Health Questionnaire (PHQ-9) (Spitzer et al., 1999). The PHQ-9 is a 9-item questionnaire designed to measure depression severity. Participants are asked to indicate how often they have been bothered by certain problems over the past 2 weeks, such as feeling down, depressed or hopeless, feeling tired or having little energy and experiencing little interest or pleasure in doing things. Items are rated on a 4-point scale ranging from 0 (“Not at all”) to 3 (“Nearly every day”) and are summed to create a depression score. The PHQ-9 has been shown to be a valid measure predicting clinical depression outcomes and changes over time (Löwe, Kroenke, Herzog, & Gräfe, 2004). Scores ≥ 5 reflect mild depression, scores ≥ 10 reflect moderate depression, scores ≥ 15 reflect moderately severe depression, and scores ≥ 20 reflect severe depression. The scale showed excellent internal consistency (Cronbach's $\alpha = .90$).

Procedure

The study was advertised on *Prolific Academic* and recruited participants aged 18 to 55 who spoke English as a first language, who were not currently suffering with a mental

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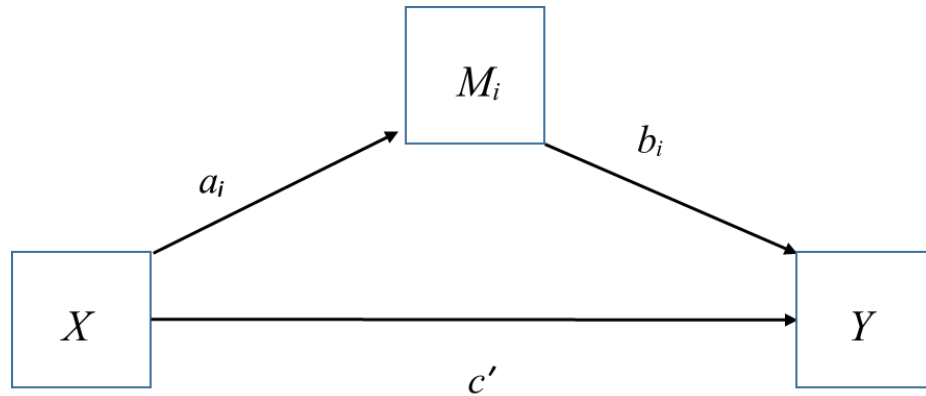
health disorder and who did not take part in *Chapter 2*. Participants were asked to download a web extension in order to run the experiment through Inquisit Web software. Programming was all done in Inquisit. Participants were asked to read a detailed information sheet and consent form before proceeding to the experiment. They first completed a batch of questionnaires in the following order (demographics, HSPS-SF, DERS, ARFQ, MHC-SF, PHQ-9), followed by two cognitive tasks, which will be described in *Chapter 6*. At the end of the experiment participants were re-directed to Prolific Academic and received reimbursement of £3.50.

Statistics

The mediation effects were tested using maximum likelihood estimator and bootstrap analyses with bias-corrected 95% confidence intervals (Preacher, Rucker, & Hayes, 2007). The total, direct and indirect effects were tested using a bootstrap estimation approach with 5000 samples (Shrout & Bolger, 2002). The indirect effect represents the difference between the total (c) and direct effects (c') of X on Y . Its significance from zero indicates that the mediator (M) accounts for a substantial proportion of X on Y . Conditional indirect effects were also tested in moderated mediation models, in order to assess whether SPS moderated the pathways between X and Y , as well as X and M . Significant interactions were followed up using Regions of Significance (RoS) tests, plotting slopes at high and low SPS (± 1 SD from mean). Analyses were conducted using Hayes 'Process' macro in SPSS (PROCESS, 2014). Simple mediation was examined using Process Model 4 (**Figure 2**) and moderated mediation of the conditional effects using Process Model 8 (**Figure 3**). All statistical models controlled for the effect of age and gender. Age may have influenced results, due to the retrospective nature of reporting childhood experiences, as the time since childhood varied

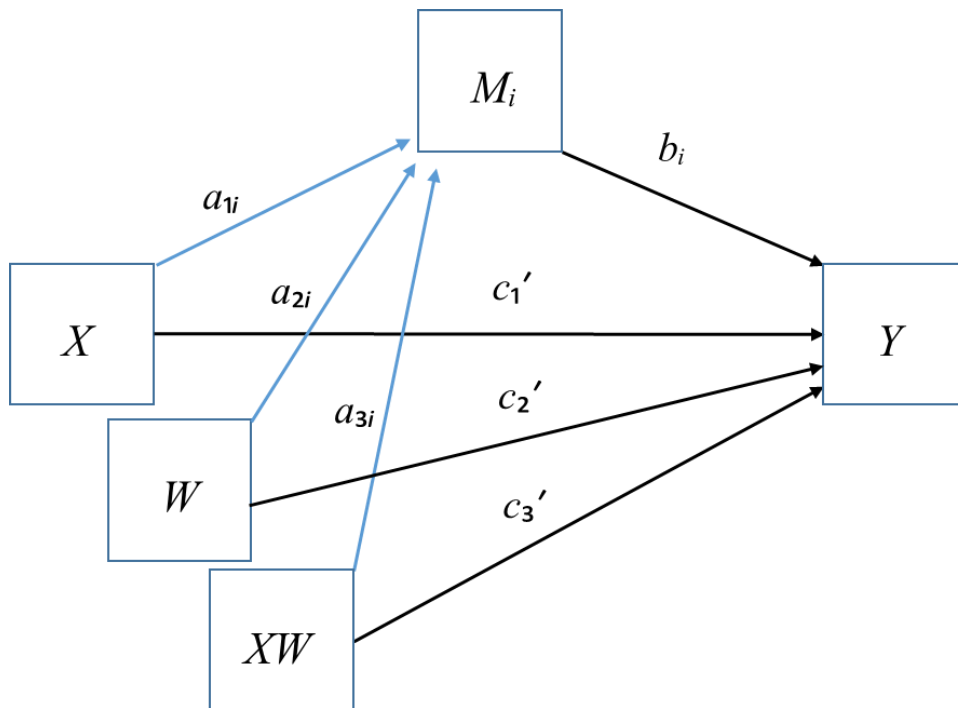
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drastically between participants. Gender may have influenced results, as mood disturbances tend to be reported more by women.



Indirect effect of X on Y through $M_i = a_i b_i$
 Direct effect of X on $Y = c'$

Figure 2. Mediation Model (Process Model 4).



Conditional indirect effect of X on Y through $M_i = (a_{1i} + a_{3i}W)b_i$
 Conditional direct effect of X on $Y = c_1' + c_3'W$

Figure 3. Moderated Mediation Model (Process Model 8).

Results

Descriptive statistics and correlations

Descriptive statistics and bivariate correlations are presented in **Table 6**. SPS showed a moderate positive correlation with DERS total. The strongest positive correlation was found with the subscale 'Goals', indicating that high SPS individuals had more difficulties in emotion regulation, particularly difficulty focusing on goal direction in relation to negative mood. SPS showed a small positive correlation with negative childhood experiences, indicating that high SPS individuals reported having more negative childhoods. SPS showed a small negative correlation with wellbeing and a moderate positive correlation with depression, indicating that high SPS individuals displayed lower mood. DERS total showed a small negative correlation with positive childhood experiences and a moderate positive correlation with negative childhood experiences, indicating that emotion regulation skills were related to experiences in childhood. DERS total showed a moderate negative correlation with wellbeing and a strong positive correlation with depression, indicating that emotion regulation was related to mood outcomes. Positive and negative childhood experiences showed a strong negative correlation. Finally, wellbeing and depression showed a moderate negative correlation.

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Table 6. Descriptive statistics (means and standard deviations) and bivariate correlations between all variables ($N = 389$)

<i>Variable</i>	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 SPS	4.51	.94	-													
2 EOE	4.80	1.30	.83	-												
3 AES	4.80	1.10	.61	.14	-											
4 LST	3.61	1.50	.80	.50	.31	-										
5 DERS total	2.51	.63	.44	.60	-.02	.32	-									
6 Non-accept	2.42	.99	.36	.42	.10	.24	.80	-								
7 Goals	3.00	.95	.60	.65	.12	.40	.75	.54	-							
8 Impulse	2.20	.84	.44	.50	.10	.33	.81	.55	.61	-						
9 Aware	2.63	.80	-.13	-.01	-.32	-.02	.34	.04	.02	.05	-					
10 Strategies	2.41	.76	.42	.51	.05	.30	.89	.70	.71	.70	.10	-				
11 Clarity	2.30	.81	.17	.30	-.15	.15	.70	.40	.32	.40	.45	.50	-			
12 Positive	3.40	.99	-.10	-.12	.02	-.04	-.25	-.21	-.12	-.16	-.12	-.31	-.12	-		
13 Negative	2.12	.91	.20	.20	.10	.11	.34	.33	.24	.32	.02	.34	.15	-.70	-	
14 Wellbeing	3.74	1.10	-.21	-.40	.14	-.12	-.52	-.33	-.40	-.30	-.30	-.51	-.42	.42	-.23	-
15 Depression	8.40	6.34	.34	.40	.06	.21	.70	.60	.52	.50	.10	.71	.41	-.33	.51	-.53

Note: SPS = Sensory Processing Sensitivity; EOE = Ease of Excitation; AES = Aesthetic Sensitivity; LST = Low Sensory Threshold; DERS = Difficulties in Emotion Regulation; Positive = positive childhood experiences; Negative = negative childhood experiences; Correlation coefficients $> .13$ are significant at the $p < .01$ level.

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Model 1: Negative childhood experiences on Depression

We first tested a moderated mediation model of negative childhood experiences on depression. Firstly, the model predicting DERS as the outcome was significant, $F(5,383) = 38.29$, $R^2 = .33$, $p < .001$. Increasing age predicted lower DERS, $\beta = -.02$, $t = -6.00$, $p < .001$. Gender had no effect on DERS, $\beta = -.01$, $t = -0.18$, $p = .855$. Increasing levels of negative childhood experiences predicted increasing levels of DERS, $\beta = .25$, $t = 5.98$, $p < .001$, and increasing levels of SPS predicted increasing levels of DERS, $\beta = .40$, $t = 9.19$, $p < .001$, however no interaction was observed, $\beta = -.01$, $t = -0.34$, $p = .730$. The full model predicting depression was also significant, $F(6,382) = 62.36$, $R^2 = .49$, $p < .001$. Age had no effect on depression, $\beta = -.00$, $t = -0.68$, $p = .493$. Gender had no effect on depression, $\beta = -.07$, $t = -0.99$, $p = .832$. Increasing levels of DERS predicted increasing levels of depression, $\beta = .52$, $t = 11.72$, $p < .001$, also increasing levels of negative childhood experiences predicted increasing levels of depression, $\beta = .26$, $t = 6.87$, $p < .001$, however SPS did not predict depression, $\beta = .07$, $t = 1.66$, $p = .097$, and there was no interaction between SPS and negative childhood experiences predicting depression, $\beta = .01$, $t = 0.34$, $p = .731$. The index of moderated mediation was not significant, $\beta = -.01$, $SE = .02$, $[CI = -.05, .04]$, therefore no moderation effects were found.

Due to the lack of moderation, we reran a simple mediation model, which showed that the relationship between negative childhood experiences on depression was partially mediated by DERS (**Figure 4**). Firstly, the total effects model was significant, $F(3,385) = 40.91$, $R^2 = .24$, $p < .001$, as increasing levels of negative childhood experiences predicted increasing levels of depression, $\beta = .45$, $t = 10.23$, $p < .001$. Increasing levels of negative childhood experiences also predicted increasing levels of DERS, $F(3,385) = 29.20$, $R^2 = .18$, $p < .001$, ($\beta = .33$, $t = 7.21$, $p < .001$). Finally, the mediation model was significant, $F(4,384)$

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$\beta = .55, t = 13.71, p < .001$, as increasing levels of DERS predicted increasing levels of depression, $\beta = .55, t = 13.71, p < .001$, and increasing levels negative childhood experiences predicted increasing levels of depression, $\beta = .27, t = 6.97, p < .001$. Although the effect of negative childhood experiences remained significant in the mediation model, the effect was reduced. The indirect coefficient was significant, $\beta = .18, SE = .02, [CI = .13, .24]$, supporting partial mediation.

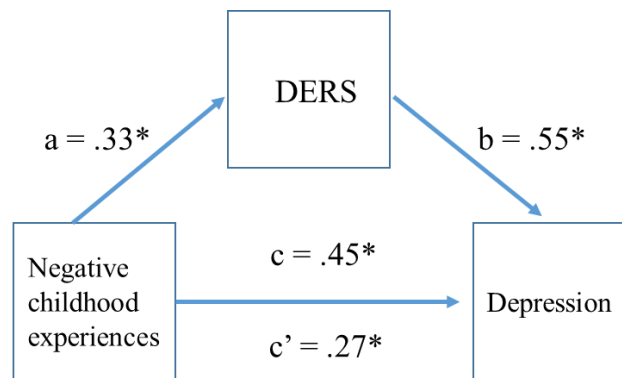


Figure 4. Standardised regression coefficients for the relationship between negative childhood experiences and depression mediated by DERS; *Significant at $p < .001$, partial mediation was supported.

Model 2: Negative childhood experiences on wellbeing

We then tested a moderated mediation model of negative childhood experiences on wellbeing. Firstly, the model predicting DERS as the outcome was significant, $F(5,383) = 38.29, R^2 = .33, p < .001$. Increasing age predicted lower DERS, $\beta = -.02, t = -6.00, p < .001$. Gender had no effect on DERS, $\beta = -.01, t = -0.18, p = .855$. Increasing levels of negative childhood experiences predicted increasing levels of DERS, $\beta = .25, t = 5.98, p < .001$, and increasing levels of SPS predicted increasing levels of DERS, $\beta = .40, t = 9.19, p < .001$, however no interaction was observed, $\beta = -.01, t = -0.34, p = .730$. The full model predicting wellbeing was also significant, $F(6,382) = 25.37, R^2 = .28, p < .001$. Age had no effect on

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wellbeing, $\beta = .00$, $t = 0.97$, $p = .330$. Gender had no effect on wellbeing, $\beta = .17$, $t = 1.86$, $p = .064$. Increasing levels of DERS predicted decreasing levels of wellbeing, $\beta = -.49$, $t = -9.30$, $p < .001$, however negative childhood experiences did not predict wellbeing, $\beta = -.05$, $t = -1.09$, $p = .276$, SPS did not predict wellbeing, $\beta = -.00$, $t = -0.16$, $p = .987$, nor did their interaction, $\beta = .02$, $t = 0.69$, $p = .487$. The index of moderated mediation was not significant, $\beta = .00$, $SE = .02$, $CI = [-.04, .05]$, therefore no moderation effects were found.

The simple mediation model showed that the relationship between negative childhood experiences on wellbeing was fully mediated by DERS (**Figure 5**). Firstly, the total effects model was significant, $F(3,385) = 11.92$, $R^2 = .08$, $p < .001$, as increasing levels of negative childhood experiences predicted decreasing levels of wellbeing, $\beta = -.21$, $t = -4.36$, $p < .001$. Increasing levels of negative childhood experiences predicted increasing levels of DERS, $F(3,385) = 29.20$, $R^2 = .18$, $p < .001$, ($\beta = .33$, $t = 7.21$, $p < .001$). Finally, the mediation model was significant, $F(4,384) = 38.08$, $R^2 = .28$, $p < .001$, as increasing levels of DERS predicted decreasing levels of wellbeing, $\beta = -.49$, $t = -10.33$, $p < .001$, but negative childhood experiences no longer predicted wellbeing, $\beta = -.04$, $t = -1.06$, $p = .290$. The indirect coefficient was significant, $\beta = -.16$, $SE = .02$, [$CI = -.22, -.11$], supporting full mediation.

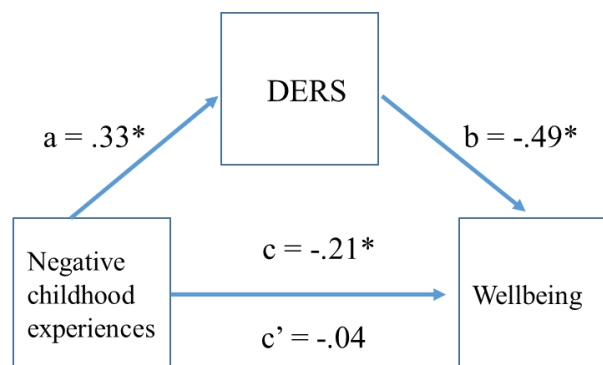


Figure 5. Standardised regression coefficients for the relationship between negative childhood experiences and wellbeing mediated by difficulties in emotion regulation

(DERS); *Significant at $p < .001$, full mediation was supported.

Model 3: Positive childhood experiences on depression

We then tested a moderated mediation model of positive childhood experiences on depression. Firstly, the model predicting DERS as the outcome was significant, $F(5,383) = 36.70$, $R^2 = .32$, $p < .001$. Increasing age predicted lower DERS, $\beta = -.02$, $t = -6.40$, $p < .001$. Gender had no effect on DERS, $\beta = -.05$, $t = -0.63$, $p = .527$. Increasing levels of positive childhood experiences predicted decreasing levels of DERS, $\beta = -.21$, $t = -5.15$, $p < .001$, and increasing levels of SPS predicted increasing levels of DERS, $\beta = .43$, $t = 10.07$, $p < .001$, however no interaction was observed, $\beta = .06$, $t = 1.75$, $p = .080$. The full model predicting depression was also significant, $F(6,382) = 55.18$, $R^2 = .46$, $p < .001$. Age had no effect on depression, $\beta = -.00$, $t = -0.94$, $p = .347$. Gender had no effect on depression, $\beta = -.12$, $t = -1.50$, $p = .132$. Increasing levels of DERS predicted increasing levels of depression, $\beta = .55$, $t = 12.16$, $p < .001$, and increasing levels of positive childhood experiences predicted decreasing levels of depression, $\beta = -.18$, $t = -4.79$, $p < .001$, increasing SPS predicted increasing depression, $\beta = .09$, $t = 2.12$, $p = .034$, but there was no interaction between SPS and positive childhood experiences predicting depression, $\beta = .01$, $t = 0.49$, $p = .621$. The index of moderated mediation was not significant, $\beta = .03$, $SE = .02$, $CI = [-.01, .09]$, therefore no moderation effects were found.

The simple mediation model, showed that the relationship between positive childhood experiences on depression was partially mediated by DERS (**Figure 6**). Firstly, the total effects model was significant, $F(3,385) = 22.57$, $R^2 = .15$, $p < .001$, as increasing levels of positive childhood experiences predicted decreasing levels of depression, $\beta = -.33$, $t = -7.19$, $p < .001$. Increasing levels of positive childhood experiences also predicted decreasing levels of DERS, $F(3,385) = 21.18$, $R^2 = .14$, $p < .001$, ($\beta = -.25$, $t(387) = -5.46$, $p < .001$). Finally, the mediation model was significant, $F(4,384) = 81.05$, $R^2 = .45$, $p < .001$, as increasing levels

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of DERS predicted increasing levels of depression, $\beta = .59$, $t = 14.77$, $p < .001$, and increasing levels positive childhood experiences predicted decreasing levels of depression, $\beta = -.18$, $t = 4.70$, $p < .001$. Although the effect of positive childhood experiences remained significant in the mediation model, the effect was reduced. The indirect coefficient was significant, $\beta = -.15$, $SE = .03$, $[CI = -.22, -.09]$, supporting partial mediation.

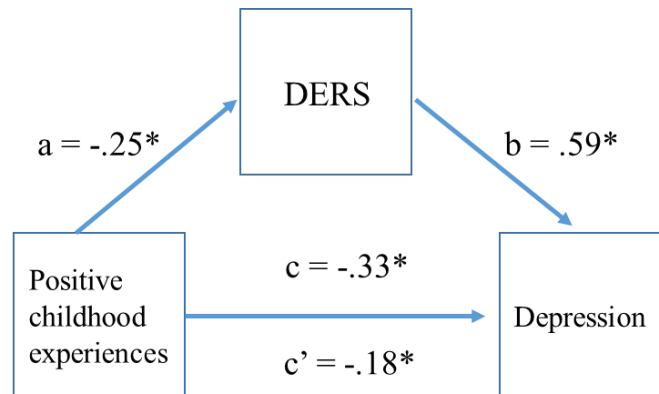


Figure 6. Standardised regression coefficients for the relationship between positive childhood experiences and depression mediated by difficulties in emotion regulation (DERS); *Significant at $p < .001$, partial mediation was supported.

Model 4: Positive childhood experiences on wellbeing

We then tested a moderated mediation model of positive childhood experiences on wellbeing. Firstly, the model predicting DERS as the outcome was significant, $F(5,383) = 36.70$, $R^2 = .32$, $p < .001$. Increasing age predicted lower DERS, $\beta = -.02$, $t = -6.33$, $p < .001$. Gender had no effect on DERS, $\beta = -.05$, $t = -0.63$, $p = .527$. Increasing levels of positive childhood experiences predicted decreasing levels of DERS, $\beta = -.21$, $t = -5.15$, $p < .001$, and increasing levels of SPS predicted increasing levels of DERS, $\beta = .43$, $t = 10.07$, $p < .001$, however no interaction was observed, $\beta = .06$, $t = 1.75$, $p = .080$. The full model predicting wellbeing was also significant, $F(6,382) = 37.90$, $R^2 = .37$, $p < .001$. Age had no effect on wellbeing, $\beta = .00$, $t = 1.80$, $p = .071$. Gender had no effect on wellbeing, $\beta = .15$, $t = 1.75$, p

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= .080. Increasing levels of DERS predicted decreasing levels of wellbeing, $\beta = -.41$, $t = -8.42$, $p < .001$, and increasing levels of positive childhood experiences predicted increasing levels of wellbeing, $\beta = .31$, $t = 7.45$, $p < .001$, however SPS did not predict wellbeing, $\beta = -.01$, $t = -0.39$, $p = .696$, and there was no interaction between SPS and positive childhood experiences predicting wellbeing, $\beta = -.01$, $t = -0.32$, $p = .744$. The index of moderated mediation was not significant, $\beta = -.02$, $SE = .01$, $[CI = -.05, .01]$, therefore no moderation effects were found.

The simple mediation model showed that the relationship between positive childhood experiences on wellbeing was partially mediated by DERS (**Figure 7**). Firstly, the total effects model was significant, $F(3,385) = 35.79$, $R^2 = .21$, $p < .001$, as increasing levels of positive childhood experiences predicted increasing levels of wellbeing, $\beta = .42$, $t = 9.37$, $p < .001$. Increasing levels of positive childhood experiences predicted decreasing levels of DERS, $F(3,385) = 21.18$, $R^2 = .14$, $p < .001$, ($\beta = -.25$, $t = -5.46$, $p < .001$). Finally, the mediation model was significant, $F(4,384) = 57.06$, $R^2 = .37$, $p < .001$, as increasing levels of DERS predicted decreasing levels of wellbeing, $\beta = -.42$, $t = -9.73$, $p < .001$, and increasing levels positive childhood experiences predicted increasing levels of wellbeing, $\beta = .31$, $t = 7.45$, $p < .001$. Although the effect of positive childhood experiences remained significant in the mediation model, the effect was reduced. The indirect coefficient was significant, $\beta = .11$, $SE = .02$, $[CI = .06, .16]$, supporting partial mediation.

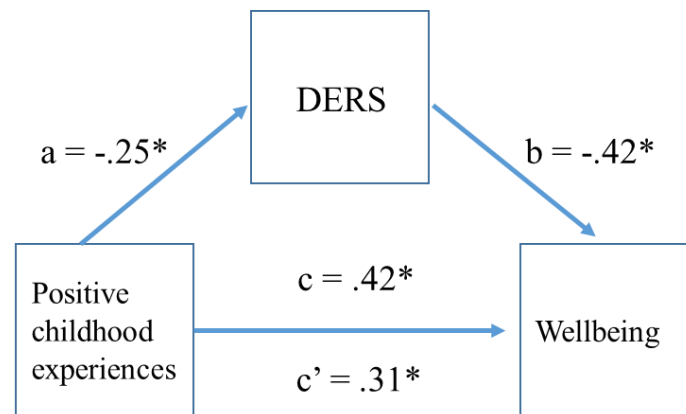


Figure 7. *Standardised regression coefficients for the relationship between positive childhood experiences and wellbeing mediated by difficulties in emotion regulation (DERS); *Significant at $p < .001$, partial mediation was supported.*

Exploratory Moderation Analyses

Although not originally intended, we decided to combine the data from *Chapter 2* with the current study, in order to test the moderation effects that we were unable to replicate. The measures were not totally comparable, as the ARFQ had one new positive item in the current study and the current study used the short version of the MHC to assess wellbeing. Yet, standardised values were used for the analysis, so we were able to merge datasets. We tested two models: the interaction between SPS and *negative* experiences predicting wellbeing and the interaction between SPS and *positive* experiences predicting wellbeing.

In the case of negative experiences, the regression model was significant overall, $F(5, 722) = 28.80$, $R^2 = .16$, $p < .001$. Increasing age predicted increasing wellbeing, $\beta = .01$, $t = 2.29$, $p = .022$. Gender predicted wellbeing, $\beta = .25$, $t = 3.63$, $p < .001$, as women reported lower wellbeing. Increasing negative childhood experiences predicted decreasing wellbeing, $\beta = -.20$, $t = -5.79$, $p < .001$, increasing SPS predicted decreasing wellbeing, $\beta = -.20$, $t = -$

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5.86, $p < .001$, and the interaction between SPS and negative experiences was significant, $\beta = -.13$, $t = -4.50$, $p < .001$. We followed this interaction up with RoS analyses. RoS on Z revealed that the regression of negative experiences on wellbeing was significant for all values of SPS that fell outside the region -3.01 and -0.94. Plotted simple slopes at high SPS (+1 *SD*) revealed that increasing negative childhood experiences predicted decreasing wellbeing, $\beta = -.33$, $t = 7.14$, $p < .001$. At low SPS (-1 *SD*), negative childhood experiences did not predict wellbeing, $\beta = -.07$, $t = 1.72$, $p = .086$. RoS on X revealed that the regression of SPS on wellbeing was significant for all values of negative experiences that fell outside the region -3.04 and -0.95. The crossover point on negative experiences was -1.57 and the PA index was 0.94, therefore the effects were only significant in response to increasing negative experiences. These results reflected a non-crossover interaction, with high SPS as a risk factor, supporting a diathesis-stress model (**Figure 8**, left).

In the case of positive experiences, the regression model was significant overall, $F(5, 722) = 24.29$, $R^2 = .14$, $p < .001$. Increasing age predicted increasing wellbeing, $\beta = .01$, $t = 2.72$, $p = .007$. Gender predicted wellbeing, $\beta = .28$, $t = 4.12$, $p < .001$, as women reported lower wellbeing. Increasing positive childhood experiences predicted increasing wellbeing, $\beta = .18$, $t = 5.35$, $p < .001$, increasing SPS predicted decreasing wellbeing, $\beta = -.24$, $t = -7.03$, $p < .001$, and the interaction between SPS and positive experiences was significant, $\beta = -.12$, $t = -3.77$, $p < .001$. We followed this interaction up with RoS analyses. RoS on Z revealed that the regression of positive experiences on wellbeing was significant for all values of SPS that fell outside the region 0.84 and 3.46. Plotted simple slopes at high SPS (+1 *SD*) revealed that increasing positive childhood experiences did not predict wellbeing, $\beta = .07$, $t = 1.41$, $p = .160$. At low SPS (-1 *SD*), increasing positive childhood experiences predicted increasing wellbeing, $\beta = .31$, $t = 7.21$, $p < .001$. RoS on X revealed that the regression of SPS on wellbeing was significant for all values of positive experiences that fell outside the region -

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4.24 and -1.25. The crossover point on positive experiences was -2.04 and the PA index was 0.97, therefore the effects were only significant in response to increasing positive experiences. These results reflected a non-crossover interaction, with low SPS as a vantage factor, supporting a vantage sensitivity model (**Figure 8**, right).

Some supplementary analyses were also conducted to explore these interactions further (Appendix C – pp. 104-111). Firstly, the models were analysed on the separate factors of SPS (i.e., EOE, LST, and AES). The results remained the same, apart from for the AES subscale and negative childhood experiences, as this model supported differential susceptibility. High AES individuals showed ‘for better and for worse’ outcomes relative to the absence and presence of negative childhood experiences. Then, analyses were conducted to assess the separate wellbeing subscales (i.e., emotional, psychological, and social). These findings were the same as reported in the main analysis, except that no interactive effects were found in predicting emotional wellbeing. Finally, the models were assessed using an SPS score residualised for the effect of wellbeing. The interaction was no longer significant with regard to negative experiences. For positive experiences the results were largely the same, although high SPS did show a beneficial effect of positive childhood experiences predicting wellbeing, although this was attenuated in comparison to at low SPS.

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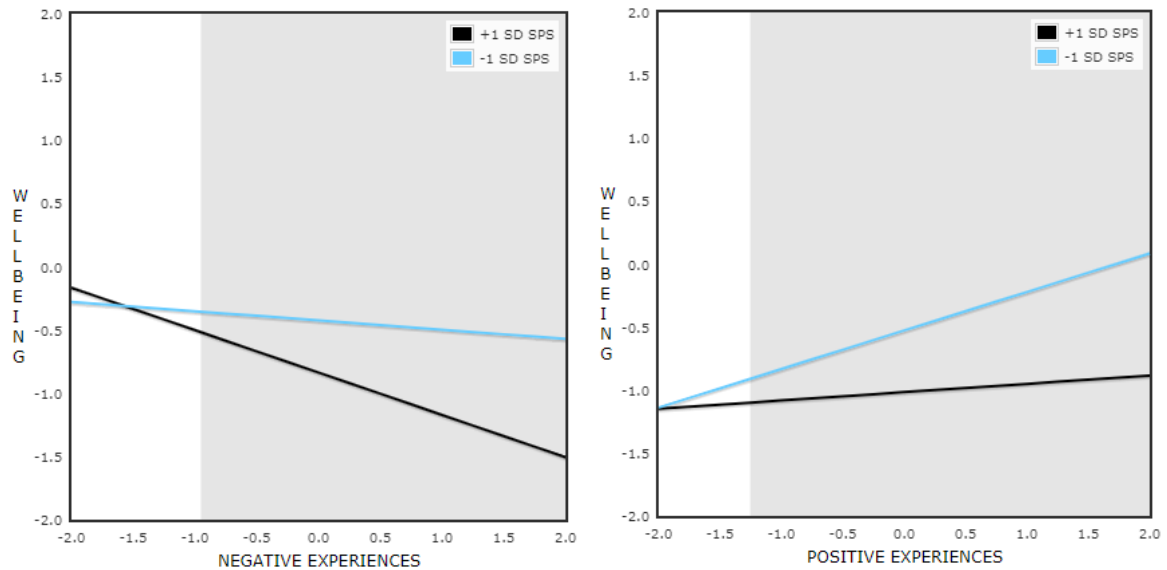


Figure 8. Moderation effects combining data from Chapter 2 and Chapter 3 ($N = 727$) for negative childhood experiences at high SPS (+1 SD) and low SPS (-1 SD) predicting wellbeing (left) and positive childhood experiences at high SPS (+1 SD) and low SPS (-1 SD) predicting wellbeing (right). Grey area denotes Regions of Significance (RoS) on X.

Discussion

We tested four moderated mediation models, but found no evidence that SPS moderated the effect of positive nor negative childhood experiences on emotion regulation skills nor wellbeing/depression. Emotion regulation played an important role in our statistical models, as it mediated the effect of childhood experiences on mental health outcomes, suggesting that it is a key factor explaining these relationships. Full mediation was supported in one of the models, as the direct effect of increasing negative childhood experiences on decreasing wellbeing was no longer significant when the indirect effect (through DERS) was considered. Emotion regulation also played a key role in explaining the effect of SPS on mental health outcomes, as the relationship between SPS and wellbeing/depression was no longer

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significant when emotion regulation was considered in the model, suggesting that emotion regulation is an intermediary mechanism. We conducted some exploratory combined moderation analyses with the sample from *Chapter 2* and supported our previous interactive effects, suggesting that failure to find moderation in the current sample may have been related to low statistical power.

We found a moderate positive correlation between SPS and DERS total, suggesting that high SPS individuals are likely to display poor emotion regulation skills. The strongest effect was found with the ‘Goals’ subscale, which describes difficulties engaging in goal direction in response to negative emotions. SPS showed a small negative correlation with the ‘Aware’ subscale, which describes lack of emotional awareness. This supports previous research (Brindle et al., 2015) and suggests that high SPS individuals tend to show better emotional awareness. Previous psychometric evaluations of the DERS subscales have shown that the ‘Aware’ subscale behaves differently than the other subscales, as it doesn’t correlate with the other subscales, and it doesn’t correlate with the expected outcomes, suggesting that it isn’t a valid emotion regulation skill (Bardeen, Fergus, & Orcutt, 2012). Therefore, we can conclude that in general high SPS was associated with poor emotion regulation skills.

SPS showed a small positive correlation with negative childhood experiences. We cannot speculate on the direction of this relationship, as it is possible that high SPS individuals are more likely to report high levels of negative childhood experiences, or that negative childhood experiences have some developmental influence on shaping high SPS. This latter explanation is related to the concept of *Biological Sensitivity to Context* (Boyce & Ellis, 2005), which suggests that early life stress can heighten sensitivity to the environment, by increasing stress reactivity. Future research would benefit from assessing SPS

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developmentally using prospective longitudinal designs in order to investigate the direction of this relationship and examine SPS within the biological sensitivity to context framework.

Positive and negative childhood experiences showed a strong negative correlation, suggesting that they were measuring a very similar construct. This is unsurprising given that we developed the ARFQ by creating new positive items to match the content of the existing negative items, in terms of early family experiences. For example, we created *item 15* (“How often did you do positive activities together as a family, like eating meals together, or going on trips?”) to match *item 16* (“How often would you say you were neglected while you were growing up, that is, left on your own to fend for yourself?”). Also, given that they were subscales from the same questionnaire, participants may have been encouraged to answer with opposite extremes of the Likert scale depending on the positivity or negativity of the item. Investigating positive experiences that lead to psychological flourishing is more of a new research interest, due to models such as differential susceptibility (Belsky & Pluess, 2009). Future research would benefit from studies investigating positive experiences that lead to long-term mental health outcomes, using multi-informant longitudinal designs. This may lead to the development of better self-report measures of experiences including key events that are known to foster positive adaptation.

In the current study, SPS did not moderate the effect of childhood experiences on DERS nor wellbeing/depression, therefore simple mediation models were conducted in all cases. Model 1 showed that DERS partially mediated the effect of increasing negative childhood experiences on increasing depression. Model 2 showed that DERS fully mediated the effect of increasing negative childhood experiences on decreasing wellbeing. Model 3 showed that DERS partially mediated the effect of increasing positive childhood experiences on decreasing depression. Finally, Model 4 showed that DERS partially mediated the effect

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of increasing positive childhood experiences on increasing wellbeing. This supports the role of emotion regulation in mental health outcomes.

Our findings supported previous research, which found that DERS fully mediated the effect of increasing negative childhood experiences on increasing depression (Schierholz et al., 2016). Our comparable model (Model 1) only supported partial mediation, which may have been due to the strong association between negative childhood experiences and depression in the current study. The previous authors used the short version of the Childhood Trauma Questionnaire (CTQ; Bernstein et al., 2003), which measures instances of emotional, physical and sexual abuse, as well as emotional and physical neglect. The ARFQ used in the current study mainly measures instances of emotional abuse and neglect, which showed a stronger association with depression, making full mediation harder to support. Emotional abuse has previously been shown to have the most significant impact on depression, which could be due to its relative high prevalence, in comparison to other types of abuse (Khan et al., 2015; Negele et al., 2015).

Our findings also supported previous research, which suggested that harsh and unsupportive parenting predicts poor emotion regulation skills (Shipman et al., 2007), particularly emotional abuse, over and above physical or sexual abuse (Burns et al., 2010). Our results expand on this research, as we also found that positive childhood experiences predicted better emotion regulation skills, which had the expected buffering effect on better mental health outcomes. While past childhood experiences cannot be changed, our research suggests that modifying skills in emotion regulation could have beneficial effects on psychological wellbeing, as emotion regulation at least partially explains these relationships.

Emotion regulation skills training practices have been developed to support existing treatment approaches, such as Cognitive-Behavioural Therapy (CBT) in the treatment of

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depression (Berking et al., 2008). While treatment effects have shown promising results, future research should focus on testing emotion regulation skills as a mechanism of change, in order to understand these pathways better (Gratz, Weiss, & Tull, 2015). In the current study, we found that the subscale ‘Strategies’, describing difficulties accessing strategies to modulate the intensity and duration of emotional responses, showed the strongest correlation with depression. Therefore, this may be a particularly useful treatment target.

We also found evidence that emotion regulation explains some of the relationship between SPS and mental health outcomes, as SPS was no longer related to wellbeing or depression when DERS were added to the model. This supports previous research which found that DERS partially mediated the effect of increasing SPS on increasing depression (Brindle et al., 2015). Therefore, high SPS individual’s mental health problems could partially be the result of poor emotion regulation skills. High SPS individuals may show heightened treatment efficacy in response to emotion regulation skills training, due to initial low levels of emotion regulation skills, as well as heightened environmental sensitivity. A study in adolescents found that high SPS individuals responded most favourably to a school-based resiliency programme, indicated by the greatest reduction in depressive symptoms, which persisted at 6 and 12 month follow-ups (Pluess & Boniwell, 2015). This highlights the need to assess individual differences in environmental sensitivity in response to treatment effects, which are not expected to be the same for everyone.

We failed to replicate the moderation effects found in *Chapter 2*, which led us to conduct some exploratory analyses by combining data from *Chapter 2*, with the current study. The combined results indicated that SPS interacted with negative childhood experiences to predict wellbeing. At high levels of SPS, increasing negative childhood experiences predicted decreasing wellbeing, while this effect was reduced at low SPS,

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suggesting that high SPS represents heightened responsivity to negative experiences, supporting diathesis-stress. Further, SPS interacted with positive childhood experiences to predict wellbeing. At high levels of SPS, positive childhood experiences had no effect on wellbeing, whereas at low levels of SPS increasing positive childhood experiences predicted increasing wellbeing. This suggests that low SPS individuals showed heightened responsivity to positive experiences, supporting vantage sensitivity. Together these results suggest that high SPS is not a marker of differential susceptibility, but of diathesis-stress, which has been supported in previous research (Booth et al., 2015; Liss et al., 2005). However, this study goes further in suggesting that high SPS may also reflect attenuated responsivity to positive experiences, which is a finding that should be investigated in future research.

Some supplementary analyses were also conducted to explore the moderation results by the separate SPS factors and the separate wellbeing subscales. The interactive results were the same for psychological and social wellbeing, but were no longer significant for emotional wellbeing. This may have been explained by low variability in the emotional wellbeing subscale, which has the smallest number of items. Only 3 items assess emotional wellbeing, in comparison to 5 and 6 items for the other subscales. Some interesting findings appeared when considering the factors underlying SPS. Results remained the same for the factors EOE and LST, but were different for AES. This latter factor showed differential susceptibility effects, as high AES individuals showed ‘for better and for worse’ outcomes relative to the absence and presence of negative childhood experiences. The AES factor is less correlated with the other factors and has been shown to associate with more positive traits, therefore it might represent the underlying plasticity factor related to SPS (Pluess et al., 2018). Therefore, future research should consider assessing the factors separately.

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Low statistical power could explain why we didn't find any moderation effects in the current sample (without combining data with *Chapter 2*). A post-hoc power analysis (conducted with *G*Power*) on the change in R^2 observed by adding the interaction between negative childhood experiences and SPS ($\Delta R^2 = .03$) revealed that in order to achieve power of .80 at the $p < .05$ level, we would have needed a sample of 441 individuals. With regard to the interaction between positive childhood experiences and SPS ($\Delta R^2 = .02$), we would have needed a sample of 646 at this level of power. The combined data-set included a sample of 727, therefore was highly powered to detect these effects. This suggests that *Chapter 2* was underpowered, particularly for the interactive effect of positive childhood experiences, therefore were likely to reflect an inflated estimate (Leon & Heo, 2009). The previous chapter reported that at high levels of SPS increasing positive experiences predicted decreasing wellbeing, whereas the combined data suggests that this effect does not exist, as positive childhood experiences had no effect on wellbeing at high SPS.

The main limitation of the current study was the use of retrospective self-report measures of childhood experiences. This is problematic as it relies on the memory and appraisal of events by the reporter, which is likely to be influenced by many factors, including personality (e.g., level of SPS). Future research should aim to conduct longitudinal research, investigating moderation of the effect of the environment in a prospective, as opposed to retrospective design. A further related limitation was the cross-sectional nature of the study, which does not allow for causality of effects to be inferred. Again, prospective longitudinal studies would be better to infer the direction of effects. However, such studies are time-consuming and costly, which was not the case for the current study. A strength of the current study was the ability to collect a large amount of data in a short time frame, which allowed for enough statistical power to detect even the smallest interactive effects by combining data with *Chapter 2*.

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In conclusion, moderated mediation was not supported in the current study, as SPS did not moderate the effect of childhood experiences on emotion regulation nor on wellbeing/depression. However, combining data with *Chapter 2* provided enough statistical power to support previous interactive effects showing that high SPS is related to heightened responsivity to negative experiences and attenuated responsivity to positive experiences. Mediation effects were found which supported previous research, as emotion regulation mediated the effect of childhood experiences on mental health outcomes. This suggests that emotion regulation may be an important treatment target for the improvement of emotional functioning. Future research would benefit from prospective longitudinal research to investigate both moderation of the environment, as well as specific life experiences which foster positive emotional adaptation, which is currently lacking in the literature.

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Appendix A: Psychometric properties of the Highly Sensitive Person Scale short form

Table 1. Factor loadings based on principal components analysis with Varimax rotation for 12 items from the Highly Sensitive Person Scale short form ($N = 389$)

<i>Item</i>		<i>EOE</i>	<i>AES</i>	<i>LST</i>	<i>Comm.</i>
4	Do you get rattled when you have a lot to do in a short amount of time?	.84			.73
8	Do you find it unpleasant to have a lot going on at once?	.84			.74
9	Do changes in your life shake you up?	.77			.61
6	Are you annoyed when people try to get you to do too many things at once?	.77			.61
12	When you must compete or be observed while performing a task, do you become so nervous or shaky that you do much worse than you would otherwise?	.71			.52
10	Do you notice and enjoy delicate or fine scents, tastes, sounds, works of art?		.79		.65
5	Are you deeply moved by the arts or music?		.76		.62
3	Do you have a rich, complex inner life?		.65		.46
1	Do you seem to be aware of subtleties in your environment?		.65		.44
7	Do you make a point to avoid violent movies and TV shows?			.80	.65
11	Are you bothered by intense stimuli, like loud noises or chaotic scenes?			.64	.66
2	Are you easily overwhelmed by things like bright lights, strong smells, coarse fabrics, or sirens close by?			.64	.64

Note: Comm. = Communality; EOE = Ease of Excitation; AES = Aesthetic Sensitivity; LST = Low Sensory Threshold; Factor loadings < .40 were suppressed.

Table 2. Descriptive statistics for the three HSPS-SF factors ($N = 389$)

	<i>No. of items</i>	<i>M (SD)</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>Cronbach α</i>
EOE	5	4.80 (1.30)	-.53	-.21	.87
AES	4	4.80 (1.10)	-.42	.21	.70
LST	3	3.61 (1.50)	.14	-.82	.70

Key points (Appendix A)

- The PCA found three components which explained 61% of total variance (**Table 1**).
- We found the exact same factor structure and item loadings as the original authors (Pluess et al., 2011).
- Overall the items showed high communality, suggesting that the HSPS-SF is a good unitary measure of SPS.
- **Table 2** shows the descriptive statistics for the factors. All factors showed good or adequate internal consistency (Cronbach's $\alpha > .70$).

3. SPS & Emotion Regulation

Appendix B: Psychometric properties for the Adapted Risky Families Questionnaire

Table 1. Factor loadings & communalities based on principal components analysis with Varimax rotation for 16 items from the ARFQ ($N = 389$)

Item		Pos.	Neg.	Comm.
13	On the whole did you feel close with your parents during your childhood, in a way that you could go to them for help?*	.83		.76
1	How often did a parent or other adult in the household make you feel that you were loved, supported, and cared for?	.81		.77
7	How often did a parent or other adult in the household ask you about any problems you were experiencing and offer guidance or support?*	.81		.68
3	How often did a parent or other adult in the household express physical affection for you, such as hugging, or other physical gestures of warmth and affection?	.79		.63
9	During your childhood did your parents go out of their way to help you, for example driving you to sports matches?*	.74		.62
15	How often did you do positive activities together as a family, like eating meals together, or going on trips?*	.72		.59
12	How often did you see your parents expressing emotional support and affection for one another?*	.70		.51
5	Would you say that the household you grew up in was well-organized and well-managed?	.53		.54
8	How often would you say that a parent or other adult in the household behaved violently toward a family member or visitor in your home?		.79	.64
4	How often did a parent or other adult in the household push, grab, shove, or slap you?		.72	.57
14	Would you say the household you grew up in was chaotic and disorganized?		.72	
10	How often would you say there was quarrelling, arguing, or shouting between your parents?		.70	.57
2	How often did a parent or other adult in the household swear at you, insult you, put you down, or act in a way that made you feel threatened?		.68	.66
6	In your childhood, did you live with anyone who was a problem drinker or alcoholic, or who used street drugs?		.66	.46
11	How often would you say there was quarrelling, arguing, or shouting between a parent and one of your siblings?		.65	.43
16	How often would you say you were neglected while you were growing up, that is, left on your own to fend for yourself?		.47	.59

Note: Pos. = positive factor; Neg. = negative factor; Comm. = communality; Factor loadings < .4 were suppressed; *indicates new positive items.

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Table 2. *Descriptive statistics for the two ARFQ factors (N = 389)*

	No. of items	M (SD)	Skewness	Kurtosis	Cronbach α
Positive	8	3.40 (.99)	-.34	-.77	.91
Negative	8	2.12 (.91)	1.00	.30	.87

Key points (Appendix B)

- The PCA found two components which explained 60% of total variance (**Table 1**).
- All positive experiences loaded onto Factor 1 (“Positive”) and all negative experiences loaded onto Factor 2 (“Negative”).
- Overall the PCA showed high communalities, suggesting that the ARFQ is an adequate measure of childhood experiences. However, item 11 (“How often would you say there was quarrelling, arguing, or shouting between a parent and one of your siblings?”) and item 6 (“In your childhood, did you live with anyone who was a problem drinker or alcoholic, or who used street drugs?”) showed lower communality.
- **Table 2** presents the descriptive statistics for each subscale. The scales displayed good or excellent internal consistency.

Appendix C

Supplementary Analyses

SPS factors

We analysed the models predicting wellbeing again using each of the factors of SPS (i.e., EOE, LST, and AES). **Table 1** presents the results from the regression models for each of the SPS factors and negative/positive childhood experiences predicting wellbeing. The models found that EOE and LST were associated with low levels of wellbeing, whereas AES had no effect on wellbeing. The interactions were significant in all models and were followed up with Regions of Significance (RoS) analyses. **Figure 1** depicts the interactions for each of the SPS factors. In the case of negative experiences (left column), EOE and LST reflected diathesis-stress, high levels of each factor predicted worse outcomes in combination with increasing negative childhood experiences. AES reflected differential susceptibility, as high AES individuals showed ‘for better and for worse’ outcomes, relative to the absence and presence of negative childhood experiences. In terms of positive experiences (right column), low levels of each factor predicted better wellbeing in combination with positive childhood experiences, supporting a vantage sensitivity model. Therefore high levels of each factor predicted less reactivity to positive experiences, although this differential effect was smaller in the case of AES, whereby high AES individuals benefitted to a similar degree from positive experiences as low AES individuals. These results were different to those reported in Chapter 2, which found no differences in results when analysing the factors of SPS separately, suggesting that larger samples are needed to detect these subtle differences. Future research may benefit from assessing the sub-factors of SPS, as AES may reflect a plasticity factor, while EOE and LST may reflect sensitivity to negative experiences only.

3. SPS & Emotion Regulation

Table 1. Supplementary analyses showing regression models for SPS factors and childhood experiences predicting wellbeing ($N = 727$).

1) Negative experiences and EOE on wellbeing: $F(5,722) = 27.28, R^2 = .15, p < .001$				
	β	$SE \beta$	t	p
Constant	-.57	.15	-3.83	.000
Negative	-.21	.03	-6.21	.000
EOE	-.23	.03	-6.72	.000
Negative x EOE	-.08	.03	-2.66	.008
2) Negative experiences and LST on wellbeing: $F(5,722) = 25.75, R^2 = .15, p < .001$				
	β	$SE \beta$	t	p
Constant	-.66	.15	-4.35	.000
Negative	-.21	.03	-6.13	.000
LST	-.18	.03	-5.19	.000
Negative x LST	-.13	.03	-4.28	.000
3) Negative experiences and AES on wellbeing: $F(5,722) = 21.97, R^2 = .13, p < .001$				
	β	$SE \beta$	t	p
Constant	-.53	.15	-3.47	.001
Negative	-.25	.03	-7.12	.000
AES	.00	.03	0.12	.904
Negative x AES	-.17	.03	-5.30	.000
4) Positive experiences and EOE on wellbeing: $F(5,722) = 23.99, R^2 = .14, p < .001$				
	β	$SE \beta$	t	p
Constant	-.67	.15	-4.50	.000
Positive	.17	.03	5.04	.000
EOE	-.25	.03	-7.19	.000
Positive x EOE	-.10	.03	-3.23	.001
5) Positive experiences and LST on wellbeing: $F(5,722) = 19.81, R^2 = .12, p < .001$				
	β	$SE \beta$	t	p
Constant	-.79	.15	-5.14	.000
Positive	.19	.03	5.48	.000
LST	-.20	.03	-5.79	.000
Positive x LST	-.09	.03	-2.94	.003
6) Positive experiences and AES on wellbeing: $F(5,722) = 11.40, R^2 = .07, p < .001$				
	β	$SE \beta$	t	p
Constant	-.69	.15	-4.41	.000
Positive	.20	.03	5.65	.000
AES	-.03	.03	-0.98	.326
Positive x AES	-.06	.03	-1.97	.049

Note: EOE = Ease of Excitation; LST = Low Sensory Threshold; AES = Aesthetic Sensitivity; Gender and age were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance.

3. SPS & Emotion Regulation

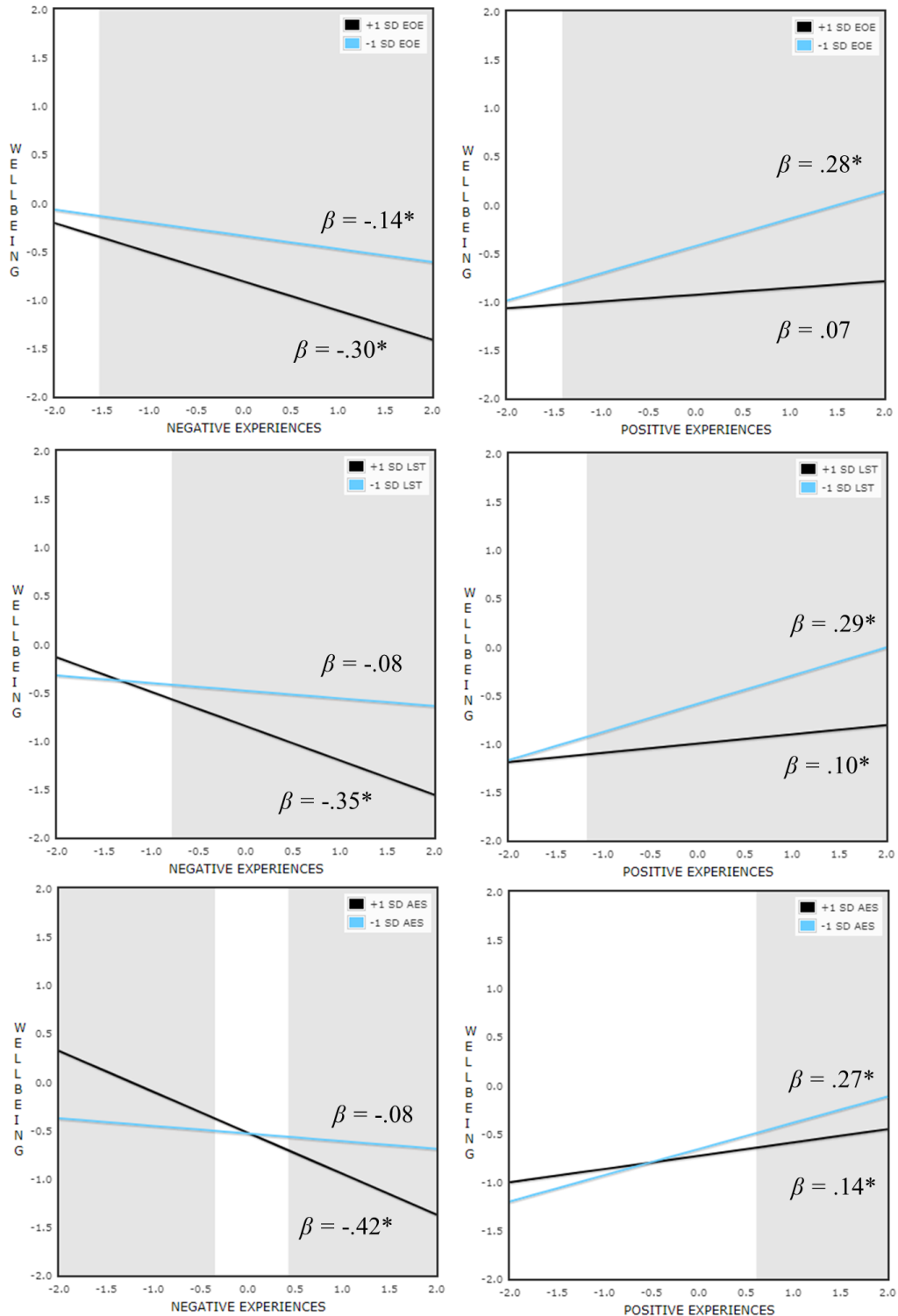


Figure 1. Sensitivity analyses showing Regions of Significance (RoS) for all interactions between the separate SPS factors (i.e., EOE, LST, and AES) and negative childhood experiences predicting wellbeing (left column) and the separate SPS factors and positive childhood experiences predicting wellbeing (right column); **Note:** Grey area denotes RoS on X; Slope depicted at high (+1 SD) and low (-1SD) for each factor; *Significant at the $p < .05$ level.

Wellbeing subscales

We then analysed the models using each of the wellbeing subscales as the outcome variable. **Table 2** presents the results from six regression models. High SPS was a risk factor for low levels of psychological and social wellbeing, but did not predict emotional wellbeing. Neither did SPS interact with childhood experiences to explain emotional wellbeing. Interactions were followed up with RoS analysis. **Figure 2** presents the interaction results. With regard to negative experiences, high SPS was a risk factor, supporting diathesis-stress, as at high SPS, increasing negative childhood experiences predicted a greater decrease in wellbeing, in comparison to at low SPS. In terms of positive experiences, low SPS was a vantage factor, supporting a vantage sensitivity model, as at low SPS, increasing positive childhood experiences predicted a greater increase in wellbeing, in comparison to at high SPS. Therefore, high SPS individuals showed attenuated responsivity to positive experiences, particularly with regard to social wellbeing, whereby positive childhood experiences had no beneficial effect.

3. SPS & Emotion Regulation

Table 2. Supplementary analyses showing regression models for SPS and negative/positive childhood experiences predicting each wellbeing subscale ($N = 727$).

1) Negative x SPS on emotional wellbeing: $F(5,722) = 7.57, R^2 = .05, p < .001$				
	β	SE β	t	p
Constant	-.43	.16	-2.68	.007
Negative	-.16	.03	-4.38	.000
SPS	-.01	.03	-0.48	.627
Negative x SPS	-.05	.03	-1.71	.087
2) Negative x SPS on psychological wellbeing: $F(5,722) = 24.13, R^2 = .14, p < .001$				
	β	SE β	t	p
Constant	-.65	.15	-4.30	.000
Negative	-.20	.03	-5.83	.000
SPS	-.15	.03	-4.45	.000
Negative x SPS	-.11	.02	-3.97	.000
3) Negative x SPS on social wellbeing: $F(5,722) = 19.53, R^2 = .11, p < .001$				
	β	SE β	t	p
Constant	-.45	.15	-2.95	.003
Negative	-.12	.03	-3.41	.001
SPS	-.24	.03	-6.89	.000
Negative x SPS	-.09	.03	-3.03	.002
4) Positive x SPS on emotional wellbeing: $F(5,722) = 7.27, R^2 = .04, p < .001$				
	β	SE β	t	p
Constant	-.52	.15	-3.28	.001
Positive	.17	.03	4.76	.000
SPS	-.04	.03	-1.18	.238
Positive x SPS	-.03	.03	-0.88	.379
5) Positive x SPS on psychological wellbeing: $F(5,722) = 19.93, R^2 = .12, p < .001$				
	β	SE β	t	p
Constant	-.79	.15	-5.17	.000
Positive	.19	.03	5.53	.000
SPS	-.19	.03	-5.57	.000
Positive x SPS	-.09	.03	-2.84	.005
6) Positive x SPS on social wellbeing: $F(5,722) = 21.02, R^2 = .12, p < .001$				
	β	SE β	t	p
Constant	-.54	.15	-3.57	.000
Positive	.14	.03	4.08	.000
SPS	-.27	.03	-7.67	.000
Positive x SPS	-.12	.03	-3.85	.000

Note: SPS = Sensory Processing Sensitivity; Gender and age were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance.

3. SPS & Emotion Regulation

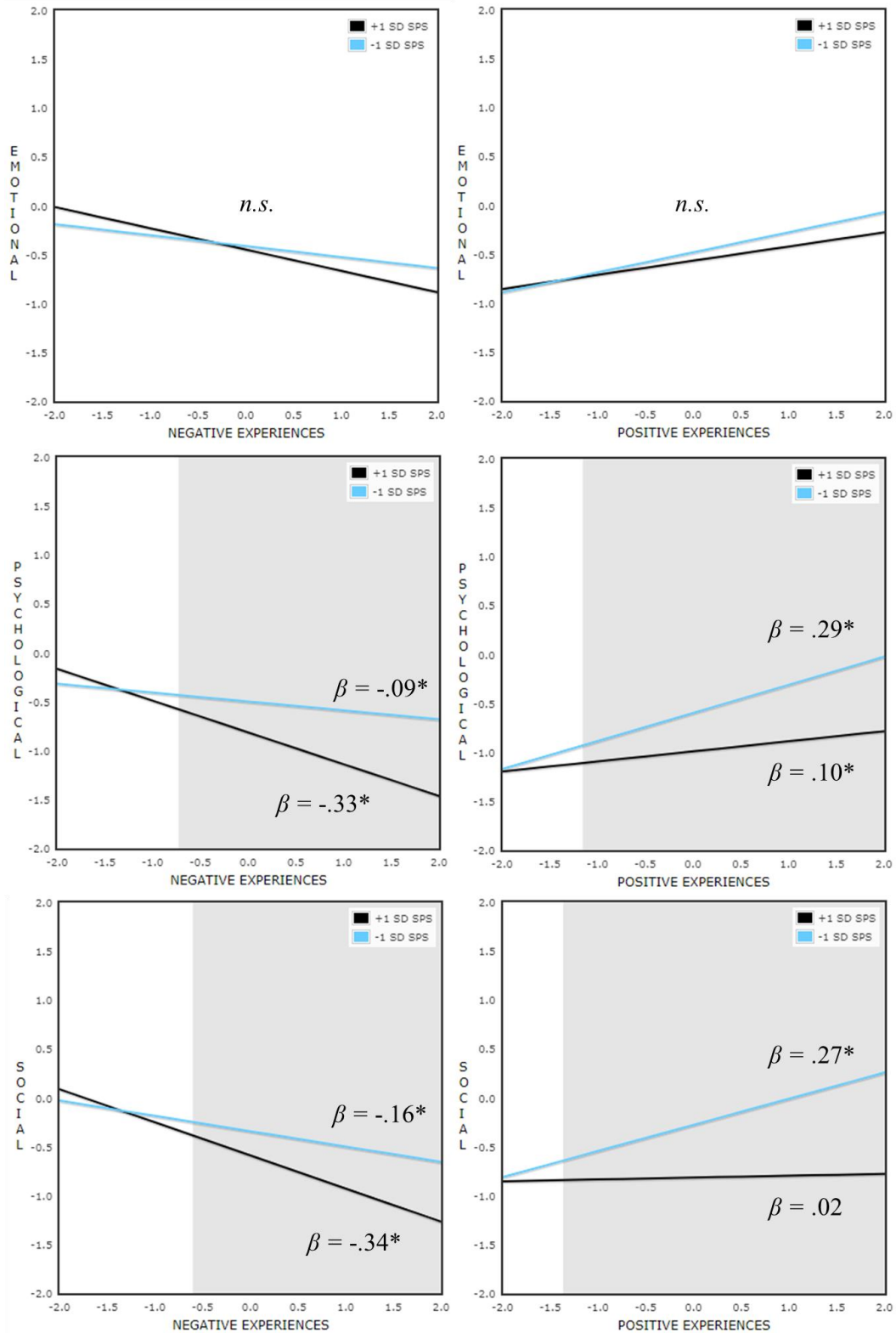


Figure 2. Regions of Significance (RoS) for interaction between SPS and negative (left) and positive (right) childhood experiences predicting emotional wellbeing (top), psychological wellbeing (middle), and social wellbeing (bottom); **Note:** Grey area denotes RoS on X; Slope depicted at high (+1 SD) and low (-1SD) SPS; *Significant at the $p < .05$ level.

SPS residualised scores

Further analyses were conducted by calculating a residualised score for SPS by controlling for the effect of wellbeing. This score was then included as a moderator in the models. The model of negative childhood experiences was significant overall, $F(5,722) = 15.89$, $R^2 = .09$, $p < .001$. Increasing age predicted increasing wellbeing, $\beta = .01$, $t = 2.13$, $p = .033$. Gender predicted wellbeing, $\beta = .20$, $t = 2.75$, $p = .006$, as women reported lower wellbeing. Increasing negative childhood experiences predicted decreasing levels of wellbeing, $\beta = -.26$, $t = -7.43$, $p < .001$. SPS (residualised) did not predict wellbeing, $\beta = .01$, $t = 0.27$, $p = .782$. The interaction between SPS and negative experiences was not significant, $\beta = -.02$, $t = -0.81$, $p = .416$. The model of positive childhood experiences was significant overall, $F(5,722) = 12.64$, $R^2 = .08$, $p < .001$. Increasing age predicted increasing wellbeing, $\beta = .01$, $t = 2.68$, $p = .008$. Gender predicted wellbeing, $\beta = .23$, $t = 3.24$, $p = .001$, as women reported lower wellbeing. Increasing positive childhood experiences predicted increasing levels of wellbeing, $\beta = .20$, $t = 5.62$, $p < .001$. SPS (residualised) did not predict wellbeing, $\beta = -.02$, $t = -0.48$, $p = .487$. The interaction between SPS and positive experiences significant, $\beta = -.10$, $t = -3.20$, $p = .001$, therefore RoS was conducted to follow this up. At high SPS, positive experiences predicted an increase in wellbeing, $\beta = .10$, $t = 2.07$, $p = .039$. Although, this effect was stronger at low SPS, $\beta = .31$, $t = 7.24$, $p < .001$. **Figure 3** shows this interaction, which reflected a differential susceptibility model. Low SPS individuals showed ‘for better and for worse’ levels of wellbeing, relative to the presence and absence of positive childhood experiences. High SPS individuals still benefitted from positive childhood experiences, but to a lesser extent.

3. SPS & Emotion Regulation

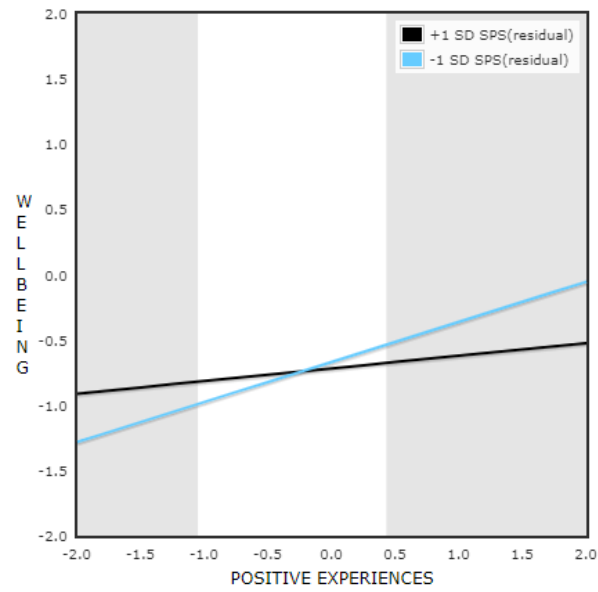


Figure 3. Interaction between SPS residualised for wellbeing and positive childhood experiences predicting wellbeing. **Note:** Grey area denotes RoS; Slope depicted at high (+1 SD) and low (-1SD) SPS.

Chapter 4

4

Does Sensory- Processing Sensitivity moderate the impact of the Environment on Psychological outcomes in Adolescents?

Abstract: Depression onset is largely attributed to the period of mid-adolescence. Stressful life events contribute to the aetiology of depression, yet individual differences in personality are thought to moderate this relationship. The current study tested whether the trait *Sensory-Processing Sensitivity* (SPS), moderates the effect of positive and negative life events on wellbeing and depression, in a young adolescent sample taking part in a wider longitudinal study. Data collected at Wave 1 ($N = 504$) and Wave 2 ($N = 450$) of the CogBIAS longitudinal study is reported. At both waves, it was found that SPS moderated the effect of negative, but not positive, life events predicting increased depression. As well as displaying higher levels of depression overall, high SPS adolescents also showed heightened responsivity to the effect of negative life events on depression, which supported a diathesis-stress model. No evidence was found that SPS moderates the effect of positive or negative life events predicting wellbeing. In conclusion, it was found that high SPS represents a vulnerability factor for the development of depression, which is related to heightened sensitivity to negative life experiences. Future research should assess SPS at multiple time points in order to investigate the causal relationship between SPS and depression. Further, targeted interventions for high SPS adolescents could be designed to ameliorate sensitivity to negative experiences, which could reduce the prevalence of depression in this high-risk age group.

Introduction

Depression is common in adolescence, with lifetime prevalence rates around 16% for females and 8% for males by the age of 18 (Merikangas et al., 2010). Depression is very debilitating and can negatively impact psychosocial functioning in adulthood, due to problematic adaptation during this sensitive developmental period (Gotlib, Lewinsohn, & Seeley, 1998; Naicker, Galambos, Zeng, Senthilselvan, & Colman, 2013). Depression in adolescents presents with similar symptoms as depression in adults, with defining features including low mood, anhedonia, as well as sleep and weight disturbances (Lewinsohn et al., 1998). Depression across the different life stages is also thought to share a similar aetiology, as it is expected that environmental risk factors (e.g., daily hassles and major negative life events) can disrupt the quality of a person's life and lead to many negative cognitive and behavioural changes, which can ultimately lead to depression (Lewinsohn et al.). For example, rumination has been shown to mediate the relationship between stressful life events and later depression (Michl, McLaughlin, Shepherd, & Nolen-Hoeksema, 2013). However, these pathways are not straightforward and are expected to be moderated by a range of further risk and protective factors, such as personality characteristics.

Theories of environmental sensitivity propose that there are individual differences in levels of responsivity to the environment. Diathesis-stress is an early theoretical model, which predicts that certain inherent characteristics can increase risk for developing psychopathology, due to heightened stress reactivity (Monroe & Simons, 1991). Differential susceptibility is a more recent framework, which suggests that characteristics representing heightened environmental sensitivity are not only likely to increase responsivity to negative experiences, but also to positive experiences, due to a general sensitivity mechanism (Belsky, 1997, 2005). Another recent framework, known as vantage sensitivity, is represented in

models showing heightened responsivity to exclusively positive experiences, thus reflecting the flipside to diathesis-stress models.

Sensory-Processing Sensitivity (SPS) is an example of a trait that reflects heightened environmental sensitivity (Booth et al., 2015). High SPS individuals are thought to be more aware of subtleties in the environment, to engage deeper cognitive processing strategies, to be more inhibited in novel situations, and to display heightened emotional reactivity (Aron & Aron, 1997; Aron et al., 2012). High SPS has been regarded as a risk factor representing diathesis-stress. For example, in a study of adults, it was found that SPS moderated the effect of negative childhood experiences on depression, as high SPS individuals showed heightened responsivity predicting greater depression (Liss et al., 2005). We also previously supported a diathesis-stress model, as high SPS individuals showed heightened responsivity to negative childhood experiences predicting lower levels of life satisfaction (Booth et al.). However, these studies can be criticised for measuring responsivity to negative life events, ignoring responsivity to positive life events, which is not a fair test of differential susceptibility (Belsky & Pluess, 2009; Manuck, 2010).

More recent studies have found that high SPS individuals show heightened responsivity to positive experiences. In a study of adolescents, it was found that high (relative to low) SPS individuals responded most favourably to a school-based resiliency intervention, as evidenced by the greatest reduction in depression symptoms at two follow-up time points (Pluess & Boniwell, 2015). In another study, it was found that high (relative to low) SPS pre-school children displayed the highest levels of externalising problems in response to negative parenting practices, as well displaying the lowest levels of externalising problems in response to positive parenting practices (Slagt et al., 2018). Together, these studies support high SPS as a mechanism of heightened environmental sensitivity, yet it is unclear which framework

best describes this trait. Studies in adults have supported diathesis-stress, while studies in younger populations have found evidence for differential susceptibility, offering the possibility that high SPS moderates the environment differently across development.

Following on from previous research and previous chapters, the current study investigated whether SPS would moderate the effect of positive and negative life events on depression and wellbeing in an adolescent sample. The HSPS has recently been developed for use in child and adolescent samples, with the aim to test environmental sensitivity effects in this age group (Pluess et al., 2018). In our previous chapters with adult samples, we found that high SPS individuals showed heightened responsivity to negative experiences predicting lower wellbeing, as well as showing attenuated responsivity to positive experiences predicting lower wellbeing. In *Chapter 3*, we failed to find moderation of the environment by SPS predicting depression, although this may have been explained by low statistical power, due to the need to test such large samples for interaction effects (Leon & Heo, 2009).

In the current study, we predicted that we would replicate our findings in adults, that high (relative to low) SPS individuals would show heightened responsivity to negative life events predicting both greater depression and lower wellbeing. We also predicted that low SPS individuals would show heightened responsivity to positive life events predicting both greater depression and lower wellbeing, in line with our previous chapters. The current study used data from a wider longitudinal study, across two time points. Wave 1 was collected when participants were on average 13 years old ($N = 504$) and Wave 2 was collected when participants were on average 14.5 years old ($N = 450$). We hypothesised that moderation effects would be the same across both time points, providing replication within the same sample.

Hypotheses

1. Increasing negative life events will predict increasing depression overall, although the effect will be stronger in high relative to low SPS adolescents.
2. Increasing negative life events will predict decreasing wellbeing overall, although the effect will be stronger in high relative to low SPS adolescents.
3. Increasing positive life events will predict decreasing depression overall, although the effect will be stronger in low relative to high SPS adolescents.
4. Increasing positive life events will predict increasing wellbeing overall, although the effect will be stronger in low relative to high SPS adolescents.

Method

Participants

Fifty-one schools were contacted in the South England area to take part in the CogBIAS longitudinal study. Twenty percent of schools that were contacted agreed to take part. The sample comprised ten cohorts from nine different schools. Eighty-one percent of the sample were from single-sex schools and the remaining were from co-education schools. At Wave 1 ($N = 504$), 55% of the sample was female and age range was 11 to 14 (mean age = 13.37, $SD = .75$). At Wave 2 ($N = 450$), 55% of the sample was female and age range was 12 to 15 (mean age = 14.55, $SD = .63$). We report a 10.9% drop-out rate between Wave 1 and 2. Reasons for dropping out included no longer wanting to participate ($n = 24$), being absent from school on the day of re-testing ($n = 18$) and leaving the school ($n = 12$).

Measures

Wave 1 and Wave 2

4. SPS in Adolescence

Child and Adolescent Survey of Experiences (CASE) (Allen & Rapee, 2012). The CASE was used to assess the number of Positive Life Events (PLE) and Negative Life Events (NLE) experienced in the last 12 months. The scale consists of 38 life events covering a broad range of experiences (e.g., “My parents split up”, “I went on a special holiday”). Participants were asked to rate whether each item happened to them in the past 12-months and whether the experience was good or bad on a 6-point scale (1 = “Really bad”, 2 = “Quite bad”, 3 = “A little bad”, 4 = “A little good”, 5 = “Quite good”, 6 = “Really good”). An optional response box was also displayed for participants to indicate a further two examples of experiences that happened to them in the same period, which was rated in the same way. PLE was computed as the number of events rated as positive by the participant (e.g., rated as 4, 5 or 6). NLE was computed as the number of events rated as negative by the participant (e.g., rated as 1, 2, or 3). Valence was attributed by the participant, as some experiences could be valued as positive by one person and negative by another. Appendix A (pp. 137-139) details each of the 38 items including the frequency of the event occurring and the mean valence given by participants at Wave 1 and Wave 2. Some supplemental analyses were also conducted, including a multiple linear regression of each item predicting depression.

The Revised Child Anxiety and Depression Scale – Short Form (RCADS-SF) (Ebesutani et al., 2012). The RCADS-SF is a 25-item questionnaire used to assess anxiety and depression in children and adolescents. For the current study we were only interested in the depression subscale, which contains ten items (e.g., “I feel sad or empty”, “Nothing is much fun anymore”). Items were rated on a 4-point scale ranging from 0 (“Never”) to 3 (“Always”). Items were summed with high scores indicating higher levels of depression. The RCADS-SF was derived from the original 47-item questionnaire (Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000) and has shown good reliability and validity in child and adolescent samples (Chorpita, Moffitt, & Gray, 2005).

4. SPS in Adolescence

Mental Health Continuum – Short Form (MHC-SF) (Keyes, 2009). The MHC-SF is a 14-item scale measuring wellbeing. It was derived from the original 40-item version designed to measure emotional, psychological and social wellbeing (Keyes, 2002). The short version includes three items related to emotional wellbeing (e.g., “happy”), six items related to psychological wellbeing (e.g., “that you like most parts of your personality”) and five items related to social wellbeing (e.g., “that you had something important to contribute to society”). For each item, participants were asked to indicate how often they felt that way during the past month, using a 6-point scale from 0 (“Never”) to 6 (“Every day”). Items were summed, with high scores indicating higher wellbeing. The scale has been validated for use in children over the age of 12 years (Keyes, 2006).

Behavioural Inhibition System/Behavioural Activation System (BIS/BAS) Child Version (Carver & White, 1994; Muris, Meesters, de Kanter, & Timmerman, 2005). The BIS/BAS Scales comprise 20-items related to four factors: (i) the Behavioural Inhibition System (BIS: e.g., “I am hurt when people scold me or tell me I have done something wrong”), (ii) the Behavioural Activation System – Reward Responsiveness (BAS-RR: e.g., “When I am doing well at something I like to keep doing it”), (iii) BAS – Drive (BAS-D: e.g., “I do everything to get the things I want”), (iv) BAS – Fun Seeking (BAS-FS: e.g., “I often do things on the spur of the moment”). Items were rated on a 4-point scale ranging from 0 (“Not true”) to 3 (“Very true”). Scores were averaged across the four factors. The BIS/BAS Child scales have shown good psychometric properties (Muris et al., 2005).

Wave 2

Highly Sensitive Child Scale (HSCS) (Pluess et al., 2018). The HSCS was developed based on the adult Highly Sensitive Person Scale (HSPS) (Aron & Aron, 1997). It contains 12-items that are suitable for children and adolescents (aged 8 – 17). The factor structure was

previously shown to be comparable to the HSPS, corresponding to Ease of Excitation (EOE: e.g., “I find it unpleasant to have a lot going on at once”), Aesthetic Sensitivity (AES: e.g., “Some music can make me really happy”) and Low Sensory Threshold (LST: e.g., “Loud noises make me feel uncomfortable”). Each item was rated on a 7-point scale from 1 (“Not at all”) to 7 (“Extremely”). Items were averaged with high scores reflecting high SPS. Three week test-retest reliability was adequate in a sample aged 8 – 11 years ($r = .68$) (Pluess et al., 2018). The HSCS was shown to correlate with similar constructs as the adult version, e.g., positively with BIS and BAS (Carver & White, 1994). We explored the factor structure with Principal Components Analysis (PCA) applying Varimax rotation (Appendix B – pp. 140-141). We found a two-factor solution, which did not support the original three-factor structure. Factor 1 contained 7 items and displayed good internal consistency (Cronbach’s $\alpha = .83$), whereas Factor 2 contained 5 items and displayed poor internal consistency (Cronbach’s $\alpha = .53$), which may have been attributed to low communality for certain items.

Procedure

Participants completed testing in computer rooms either at their school or at the Department of Experimental Psychology, University of Oxford. Testing was completed in groups, which ranged in size from 6 to 50 participants at a time, depending on the size of the cohort and the computer room. Participants were given a unique participant number printed on a large piece of paper, which they were told to enter carefully when prompted on the computer tasks. They were asked to conduct testing in exam conditions, i.e., not talking or looking at their neighbours computer screen. Participants were told to raise their hand if they did not understand the instructions, but otherwise to work through the computer tasks and questionnaires on their own, following the written instructions on the screen. Behavioural tasks were programmed and presented in *Inquisit* software and questionnaires were

4. SPS in Adolescence

programmed and presented in *Limesurvey*. Participants completed a total of two hours of testing at each wave, which included two different sessions consisting of a batch of behavioural tasks and questionnaires presented in the same order (see Appendix C – p. 142 – for full list of measures). Participants were given a break in between the two sessions. At least two research assistants and one teacher were always present during testing. At the end of the session participants were thanked, debriefed, and given a £10 Amazon voucher.

Statistics

Moderated regression models were tested in SPSS and significant interactions were followed up with Regions of Significance (RoS) analyses using a freely available web-based program (<http://www.yourpersonality.net/interaction/>). SPS was tested as a moderator of effects at Wave 1 and at Wave 2, in order to provide a study replication within the sample. However, the assessment of SPS was conducted at Wave 2, therefore an assumption was made that SPS is a stable personality construct, which may not have been correct.

Results

Descriptive statistics

Table 1 displays descriptive statistics (number completed, mean, standard deviation, and Cronbach's alpha) for all variables at Wave 1 and Wave 2. Paired samples t-tests were also conducted to assess change in score from Wave 1 to Wave 2. Level of BIS was stable, level of BAS-FS was stable, while BAS-RR decreased, $t(422) = 4.69, p < .001, d = .25$, and BAS-D increased, $t(422) = -2.31, p = .020, d = .11$. Depression increased, $t(446) = -5.20, p < .001, d = .20$. Wellbeing increased, $t(408) = -3.93, p < .001, d = .18$. Number of NLE was stable,

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but number of PLE decreased, $t(441) = 3.61, p < .001, d = .16$. SPS could not be tested in this way as it was only measured once at Wave 2.

Table 1. Descriptive statistics including number completed, mean, standard deviation, and Cronbach's alpha (α) at Wave 1 ($N = 504$) and Wave 2 ($N = 450$)

	<i>Wave 1</i>				<i>Wave 2</i>			
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>α</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>α</i>
SPS	-	-	-	-	424	4.36	.89	.80
BIS	473	1.94	.50	.69	449	1.96	.49	.72
BAS-RR	473	2.19	.53	.74	449	2.05	.57	.80
BAS-D	473	1.16	.68	.78	449	1.24	.66	.79
BAS-FS	473	1.75	.64	.69	449	1.69	.65	.71
Depression	501	8.25	5.39	.90	450	9.45	6.15	.88
Wellbeing	456	40.93	12.23	.94	447	43.43	15.12	.94
NLE	494	5.51	4.16	n/a	450	5.32	4.04	n/a
PLE	494	6.90	3.38	n/a	450	6.35	3.36	n/a

Note: SPS = Sensory-Processing Sensitivity; BIS = Behavioural Inhibition; BAS-RR = Reward Responsiveness; BAS-D = Drive; BAS-FS = Fun Seeking; NLE = Negative Life Events, PLE = Positive Life Events; Cronbach's alpha was not applicable for the life events checklists.

Correlations

A correlation table is shown in **Table 2**. SPS showed a moderate positive correlation with BIS and a small positive correlation with BAS-RR, indicating that high SPS was related to greater behavioural inhibition and reward seeking. SPS showed a moderate positive correlation with depression at Wave 1 and Wave 2 and showed a small negative correlation

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with wellbeing at Wave 1 and Wave 2, indicating that high SPS was related to low mood. SPS was uncorrelated with life events, with the exception of a small negative correlation with PLE measured at Wave 1, indicating that high SPS adolescents reported less positive experiences. Depression at Wave 1 was highly positively correlated with depression at Wave 2. Wellbeing at Wave 1 was moderately positively correlated with wellbeing at Wave 2. NLE at Wave 1 showed a moderate positive correlation with NLE at Wave 2. Similarly, PLE at Wave 1 showed a moderate positive correlation with PLE at Wave 2, indicating that life experiences were relatively stable across time. PLE and NLE showed a small to moderate positive correlation across both time points, indicating that these measures were divergent.

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Table 2. Bivariate correlations between variables assessed at Wave 1 (N = 504) and Wave 2 (N = 450)

Variable	1	2	3	4	5	6	7	8	9	10	11	12
Wave 2												
1. SPS	-											
2. BIS	.59*	-										
3. BAS-RR	.26*	.35*	-									
4. BAS-D	.06	.00	.42*	-								
5. BAS-FS	-.05	.00	.51*	.44*	-							
6. Depression	.37*	.25*	-.10	.02	-.05	-						
7. Wellbeing	-.17*	-.20*	.20*	.11	.21*	-.61*	-					
8. NLE	.11	.07	.04	.17*	.11	.34*	-.17*	-				
9. PLE	-.08	-.08	.06	.15*	.12	.03	.13*	.31*				
Wave 1												
10. Depression	.35*	.17*	-.04	.04	-.03	.62*	-.35*	.21*	.03	-		
11. Wellbeing	-.16*	-.11	.19*	.08	.19*	-.44*	.57*	-.05	.14*	-.50*	-	
12. NLE	.03	.01	.02	.08	.16*	.23*	.47*	.46*	.31*	.31*	-.07	-
13. PLE	-.13*	-.11	.02	.10	.14*	-.06	.14*	.14*	.41*	-.07	.25*	.42*

Note: SPS = Sensory Processing Sensitivity; BIS = Behavioural Inhibition; BAS-RR = Reward Responsiveness; BAS-D = Drive; BAS-FS = Fun Seeking; NLE = Negative Life Events; PLE = Positive Life Events; *Significant at $p < .01$ level.

Wave 1 Analyses

We tested moderation effects at Wave 1 with four regression models (**Table 3**). Model 1 explained 21% of variance in depression: increasing SPS predicted increasing depression, increasing NLE predicted increasing depression, and there was a significant interaction between SPS and NLE predicting depression, which was later followed up with RoS analyses. Model 2 explained 4% of variance in wellbeing: increasing SPS predicted decreasing wellbeing, NLE did not predict wellbeing, and there was no interaction between SPS and NLE predicting wellbeing. Model 3 explained 13% of variance in depression: increasing SPS predicted increasing depression, PLE did not predict depression, and there was no interaction between SPS and PLE predicting depression. Model 4 explained 8% of variance in wellbeing: increasing SPS predicted decreasing wellbeing, increasing PLE predicted increasing wellbeing, and there was no interaction between SPS and PLE predicting wellbeing.

Table 3. *SPS moderating the effect of NLE and PLE on Wellbeing and Depression outcomes at Wave 1 (N = 504)*

<i>Variable</i>	β	<i>t</i>	<i>p</i>
Model 1: SPS x NLE predicting Depression, $F(5,417) = 22.53$, $R^2 = .21$, $p < .001$			
constant	1.28	0.96	.336
SPS	.32	7.07	<.001
NLE	.29	6.39	<.001
SPS x NLE	.08	2.24	.025
Model 2: SPS x NLE predicting Wellbeing, $F(5,403) = 3.35$, $R^2 = .04$, $p < .001$			
constant	.28	0.19	.846
SPS	.13	-2.75	.006
NLE	.09	1.85	.064

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SPS x NLE	-.07	-1.65	.098
Model 3: SPS x PLE predicting Depression, $F(5,417) = 12.78$, $R^2 = .13$, $p < .001$			
constant	1.69	1.21	.22
SPS	.34	7.19	<.001
PLE	-.01	-0.26	.789
SPS x PLE	-.02	-0.44	.658
Model 4: SPS x PLE predicting Wellbeing, $F(5,403) = 7.07$, $R^2 = .08$, $p < .001$			
constant	.24	0.17	.865
SPS	-.13	-2.65	.008
PLE	.25	4.82	<.001
SPS x PLE	.03	0.59	.553

Note: SPS = Sensory-Processing Sensitivity; NLE = Negative Life Events; PLE = Positive Life Events; Variables were standardised prior to analysis; Gender and age were controlled for in all models and neither were significant predictors.

RoS Analyses (Wave 1)

We probed the significant interaction from Model 1 with RoS analyses (**Figure 1**). RoS on Z revealed that the regression of NLE on depression was significant for all values of SPS that fell above -1.51. Plotted simple slopes at high SPS (+1 *SD* from mean) revealed that increasing NLE predicted increasing depression, $\beta = .38$, $t = 5.85$, $p < .001$. At low SPS (-1 *SD* from mean), increasing NLE predicted increasing depression, $\beta = .20$, $t = 3.26$, $p < .001$, albeit to a lesser extent. RoS on X revealed that the regression of SPS on depression was significant for all values of NLE that fell above -1.73. The crossover point on NLE was -3.67 and the PA index was 1.00, supporting a diathesis-stress model.

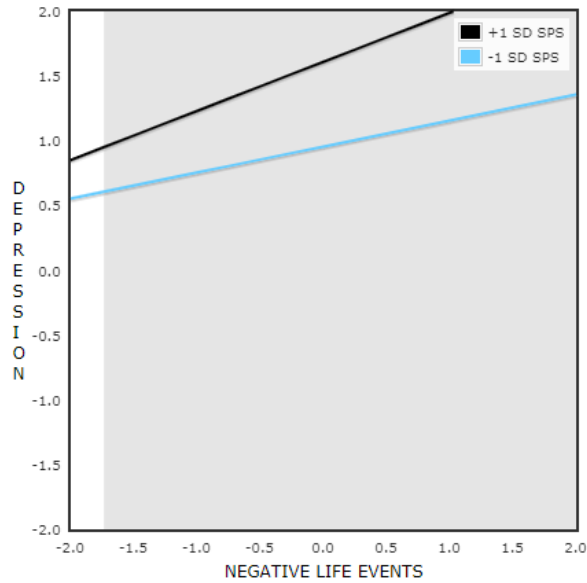


Figure 1. *Interaction between Negative Life Events at Wave 1 and SPS predicting Depression at Wave 1. Variables are standardised and presented at + and – 2 SD. Moderation represented at High (+1 SD from mean) and Low (-1 SD from mean) SPS.*

Wave 2 Analyses

We tested moderation effects at Wave 2 with four regression models (**Table 4**). Model 1 explained 24% of variance in depression: increasing SPS predicted increasing depression, increasing NLE predicted increasing depression, and there was a significant interaction between SPS and NLE predicting depression, which was later followed up with RoS analyses. Model 2 explained 5% of variance in wellbeing: increasing SPS predicted decreasing wellbeing, increasing NLE predicted decreasing wellbeing, and there was no interaction between SPS and NLE predicting wellbeing. Model 3 explained 15% of variance in depression: increasing SPS predicted increasing depression, PLE did not predict depression, and there was no interaction between SPS and PLE predicting depression. Model 4 explained 4% of variance in wellbeing: increasing SPS predicted decreasing wellbeing,

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increasing PLE predicted increasing wellbeing, and there was no interaction between SPS and PLE predicting wellbeing.

Table 4. SPS moderating the effect of NLE and PLE on Wellbeing and Depression outcomes at Wave 2 ($N = 450$)

Variable	β	t	p
Model 1: SPS x NLE predicting Depression, $F(5,417) = 26.81$, $R^2 = .24$, $p < .001$			
constant	-.46	-0.32	.747
SPS	.30	6.98	<.001
NLE	.25	5.88	<.001
SPS x NLE	.10	2.33	.020
Model 2: SPS x NLE predicting Wellbeing, $F(5,415) = 6.77$, $R^2 = .07$, $p < .001$			
constant	.78	-.48	.628
SPS	-.12	-2.56	.011
NLE	-.11	-2.28	.023
SPS x NLE	-.09	-1.90	.057
Model 3: SPS x PLE predicting Depression, $F(5,417) = 16.60$, $R^2 = .16$, $p < .001$			
constant	-.72	-0.48	.629
SPS	.34	7.33	<.001
PLE	.07	1.49	.135
SPS x PLE	-.00	-0.02	.976
Model 4: SPS x PLE predicting Wellbeing, $F(5,415) = 5.54$, $R^2 = .06$, $p < .001$			
constant	.74	0.45	.648
SPS	-.13	-2.73	.007
PLE	.09	1.80	.071
SPS x PLE	-.02	-0.52	.603

Note: SPS = Sensory-Processing Sensitivity; NLE = Negative Life Events; PLE = Positive Life Events; Variables were all standardised prior to analysis; Gender and age were controlled for in all models – gender was a significant predictor, as girls showed higher depression and lower wellbeing.

RoS Analyses

We probed the interaction from Model 1 with RoS analyses (**Figure 2**). RoS on Z revealed that the regression of NLE on depression was significant for all values of SPS that fell above -1.20. Plotted simple slopes at high SPS (+1 SD from mean) revealed that increasing NLE predicted increasing depression, $\beta = .36$, $t = 5.60$, $p < .001$. At low SPS (-1

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SD from mean), increasing NLE predicted increasing depression, $\beta = .16$, $t = 2.51$, $p = .012$, albeit to a lesser extent. RoS on X revealed that the regression of SPS on depression was significant for all values of NLE that fell above -1.48. The crossover point on NLE was -2.96 and the PA index was 0.99, supporting a diathesis-stress model.

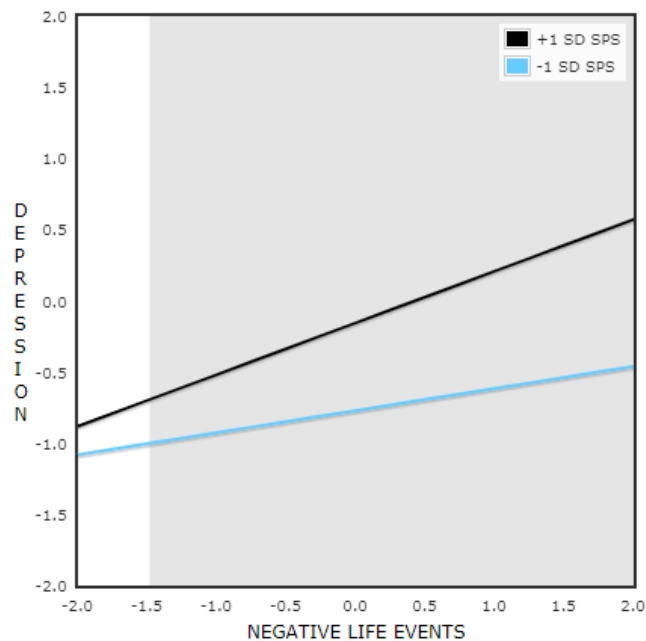


Figure 2. Interaction between Negative Life Events at Wave 2 and SPS predicting Depression at Wave 2. Variables are standardised and presented at + and - 2 SD. Moderation represented at High (+1 SD from mean) and Low (-1 SD from mean) SPS.

Supplementary analyses

Some supplementary analyses were conducted to explore these associations further (Appendix D – pp. 143-147). Firstly, the interaction was explored using each SPS factor (i.e., EOE, LST, and AES) as the moderating variable. The interactive results remained the same for the factors EOE and LST. However, AES did not interact with NLE to predict depression, therefore did not reflect diathesis-stress. Then, the interaction was explored using each wellbeing subscale (i.e., emotional, psychological, and social) as the outcome variable. The interaction did not reach significance for the overall scale, however the model of emotional

wellbeing was significant, supporting a diathesis-stress model. High SPS adolescents showed heightened environmental sensitivity, reflected by a greater effect of NLE on decreasing wellbeing. Finally, due to the shared variance between SPS and wellbeing outcomes, SPS scores were residualised for the effect of affective outcomes and tested as moderators for the effect of both NLE and PLE on wellbeing and depression. However, this did not change the results, as only the model of SPS and NLE on depression showed interactive effects, with high SPS reflecting a risk factor, represented by diathesis-stress.

Discussion

We found evidence that high SPS in adolescents reflects heightened environmental sensitivity, in a similar way as it does in adults. SPS moderated the effect of NLE on depression, as high SPS individuals showed heightened responsivity to NLE predicting greater levels of depression at both waves. We did not observe any moderation effects predicting wellbeing, as we did in previous chapters, which may have been related to the validity of using this measure in younger populations. Supplementary analyses revealed that interactive effects were present for the emotional wellbeing subscale, with high SPS reflecting heightened sensitivity within a diathesis-stress framework, in the same way as the model of depression. No interactive effects with PLE were found, as were previously in our adult samples, which may have been related to the different style of questionnaire used to report experiences, which was not a strong predictor of mood outcomes in the current study.

We found clear evidence supporting a diathesis-stress model of environmental sensitivity, as opposed to differential susceptibility. This was evident by the non-crossover interactions between NLE and SPS predicting depression, as well as the PA indices of around 1.00, which showed that high SPS individuals reported greater levels of depression than low

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SPS individuals at all levels of NLE, i.e., even in the absence of NLE. High SPS can therefore be regarded as a risk factor for depression in adolescence, which is related to greater sensitivity to negative experiences. Previous research showed that high SPS adolescents responded most favourably to a school-based resiliency intervention (Pluess & Boniwell, 2015), and that high SPS children responded most favourably to positive parenting practices (Slagt et al., 2018), suggesting that high SPS may reflect a more general mechanism of environmental sensitivity. However, our research in adults and adolescents does not support this claim, suggesting that high SPS is mainly a risk factor for poor mental health, supporting a model of diathesis-stress.

It has been suggested that in order to support differential susceptibility, the moderator variable of interest should not be related to the outcome, as a crossover interaction would eliminate this main effect (Belsky et al., 2007). We found that high SPS was a consistent predictor of low wellbeing and high depression, which supports our conclusion that high SPS reflects diathesis-stress and not differential susceptibility. To our knowledge only one previous study assessed the association between SPS and depression in adolescents and found no correlation (Pluess & Boniwell, 2015). However, in that study, SPS scores were residualised in a regression model for negative affect, which could have explained the lack of correlation with depression. Although, in our supplementary analyses, we residualised SPS for both wellbeing and depression, which did not change the results. SPS remained a risk factor predicting both a direct association with wellbeing and depression, as well as reflecting heightened sensitivity to NLE predicting greater depression.

In the current study, we did not replicate the three-factor structure of SPS found in adults (Smolewska et al., 2006) and in previous child/adolescent samples (Pluess et al., 2018). We found a two-factor structure, which did not reflect any meaningful dissociation, e.g.,

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positive and negative items were mixed between the factors. Item 7 (“I get nervous when I have a lot to do in a little time”) showed particularly low communality, suggesting that it does not reflect anything specific to the concept of SPS in adolescents. Future research might consider developing a measure of SPS that is specific to younger populations, as the HSCS was developed by re-wording items from the adult scale, however SPS may manifest differently in adolescents, compared to adults. Despite this, in our supplementary analyses, we computed the factor scores and re-analysed the interactive effects using each factor instead of the total score. The factors EOE and LST reflected the same diathesis-stress interaction as the total score, however AES did not interact with NLE predicting depression. However, AES still reflected a risk factor, as there was a direct relationship between high levels of AES and increasing depression, therefore it did not predict more positive outcomes.

In comparison to our previous chapters, we found no moderation effects predicting wellbeing. This may have been related to the fact that wellbeing, measured with the MHC, is not a completely valid measure in adolescents, as it was originally developed to assess wellbeing in adults (Keyes, 2002). Although it has been suggested that the scale is valid to use in samples aged 12 years and older (Keyes, 2006), the items were not amended for younger populations. Therefore, some of the items may have been too difficult for our young sample to comprehend, or the construct of wellbeing may present differently in adolescents compared to adults. We found that across time, wellbeing scores were less stable than depression scores in the current sample, as indicated by lower test-retest correlations, which supports this suggestion. Future research should investigate the construct of wellbeing, specifically in child and adolescent samples, as it may present differently to wellbeing in adults. Our supplementary analyses revealed that the emotional wellbeing subscale reflected a diathesis-stress model, similar to our findings in adults. High SPS adolescents showed heightened sensitivity to NLE predicting worse levels of emotional wellbeing. Therefore, the

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emotional wellbeing subscale may be a more relevant construct in adolescence, compared to psychological and social wellbeing.

We supported the effects of the environment on the prediction of our mood outcomes in most, but not all models. The effect of NLE on depression was robust at both time points, as increasing NLE predicted increasing depression. There was no effect of PLE on depression at either time point, despite our prediction that decreasing PLE would predict increasing depression. There was however an effect of PLE on wellbeing at Wave 1, as increasing PLE predicted increasing wellbeing. Finally, the effect of NLE on wellbeing was divergent across time, as increasing NLE predicted decreasing wellbeing at Wave 2, while this effect was not present at Wave 1. Future research should attempt to replicate these findings, including other measures of life experiences that may be highly predictive, such as traumatic experiences, as well as exceptionally positive experiences.

Our moderation results were the same at both waves, providing evidence of replication within the same sample. However, given that SPS was only measured once at Wave 2, we applied it as a moderator of the effects at Wave 1 on the assumption that SPS reflects a stable personality trait. This could be considered a limitation of the current study design, although we were unable to include the HSCS at Wave 1, as it had not yet been developed. We recently completed data collection for Wave 3 ($N = 416$) and although data was not processed for the current study, we checked the retest reliability of SPS scores at Wave 2 and Wave 3. This analysis revealed that SPS was a stable construct, as the scores were strongly positively correlated ($ICC3k = .76$). This level of stability is considered good for a trait level measure (Koo & Li, 2016). In future research, we will be able to test the interaction between SPS and life events measured at Wave 2 predicting depression at Wave 3, which will provide a better test of the prospective effects on mood outcomes.

Related to this, a limitation of the current study was the cross-sectional design, as we cannot be sure of the direction of effects. Longitudinal designs are better for inferring causality. For example, structural equation modelling, such as latent growth curve analysis, can model change in an outcome over a period of time (using a minimum of three time points), including time varying processes (e.g., life events) and time invariant processes (e.g., SPS) (Preacher, Wichman, MacCallum, & Briggs, 2008). Moderation effects by SPS could be investigated with such models in future research to investigate the direction of effects predicting the trajectory of depressive symptomatology in adolescents. Another method for inferring causality is the cross-lagged panel design, which investigates the direction of effects between two variables, measured at two different time points, by controlling for the autocorrelations between the variables (Kenny, 2005). This could be used in future research to investigate whether SPS is in fact a causal factor, predicting depression.

Another limitation of the current study was the type of life events measured, which could be considered fairly normative, in comparison to more serious negative life events, such as instances of child abuse, which have known strong associations with depression (Negele et al., 2015; Widom et al., 2007). Future research could investigate whether and how SPS moderates the effect of more serious negative life experiences, as we would expect that high SPS individuals would show heightened responsivity predicting worse outcomes. Conversely, moderation effects of more significant positive life events could be examined in future research, such as responses to positive psychological interventions.

A further limitation was the lack of power to detect interactive effects. For example, we calculated the change in R^2 by either adding the main effect of SPS predicting depression ($\Delta R^2 = .12$), or the interaction between SPS and NLE predicting depression ($\Delta R^2 = .01$). A post-hoc power analysis (conducted using G*Power) revealed that in order to achieve power

of .80 at the $p < .05$ level, we would have needed to test 104 individuals for the main effect, in contrast to 1095 individuals in order to detect the interactive effect. This shows that our study was underpowered to detect interactive effects. Future research should consider recruiting larger samples to detect such effects.

Our research suggests that high (relative to low) SPS adolescents are at increased risk of developing depression, which is related to heightened responsivity to negative life events. Future research should consider developing targeted interventions for this at-risk population. For example, interventions designed to improve emotion regulation following negative experiences might prove especially beneficial. Learning to focus on the positive aspects of an event, rather than the negative aspects, has proven to be beneficial for wellbeing (Seligman, Ernst, Gillham, Reivich, & Linkins, 2009). The Penn Resiliency Program (PRP) is an example of a school-based resiliency intervention designed to reduce depression by increasing students' ability to handle day-to-day stressors. A meta-analysis of 17 studies found significant improvements in depressive symptoms following PRP compared to a control condition, at post intervention, as well as two follow-up time points (Brunwasser, Gillham, & Kim, 2009). Future research should consider investigating whether SPS moderates the beneficial effect of such resiliency interventions. For example, a study conducted in the UK found that high SPS adolescents responded most favourably to a similar school-based intervention (Pluess & Boniwell, 2015). Future research should consider attempting to replicate this finding in larger samples of adolescents taking part in randomised controlled trials.

In conclusion, we supported our prediction that high SPS in adolescents would reflect heightened environmental sensitivity, in a similar way as found in adults. We supported a diathesis-stress model, as high SPS predicted higher depressive symptomatology at two time

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points, which was related to increasing responsivity to the effects of negative experiences. We did not support this model when using wellbeing as an outcome, however this may have been related to the measure of wellbeing used, which was not specifically developed for use in adolescent populations. Future research should investigate our model longitudinally, in order to support the direction of effects. Following on from this, future research should consider developing targeted interventions for high SPS adolescents in order to improve the ability to cope with stressful life events, which could reduce the prevalence of depression in adolescents.

Appendix A: Exploration of the Child Adolescent Survey of Experiences (CASE)**Table 1.** Frequencies and mean ratings (high numbers are positive) from the 38-item CASE at Wave 1 (N=504) and Wave 2 (N=450).

Item	Experience	%	Wave 1		Wave 2		
			Mean	SD	%	Mean	SD
1	We moved house	23	5.04	1.12	19	4.96	1.18
2	I won a prize, award or contest	73	5.71	.57	71	5.61	.69
3	My parent(s) stayed away from home overnight (e.g. work, holiday, hospital)	59	3.87	1.30	68	4.10	1.30
4	I got a new boyfriend or girlfriend	23	5.31	.99	27	5.21	1.15
5	My parent(s) started a new job	37	5.03	1.03	35	4.92	1.11
6	Someone special to me moved away (who is <u>not</u> in your family)	24	1.97	.84	22	2.07	1.08
7	Someone in my family was really sick or injured	56	1.50	.81	53	1.62	.86
8	My parent(s) had a baby/found out they are having a baby	10	5.07	1.41	7	5.00	1.17
9	My parent(s) had to see my school principal	17	3.32	1.70	13	3.00	1.71
10	I stayed away from home overnight (e.g., camp, trip, hospital)	85	5.06	1.11	89	5.11	1.00
11	Someone came to live with our family	22	4.51	1.20	21	4.36	1.30
12	I was teased or bullied	32	2.03	1.04	30	2.13	.96
13	My pet died, got sick, lost or injured	35	1.59	.88	34	1.85	1.03
14	I had a big argument with someone in our family	42	1.86	.98	45	2.10	1.07
15	I was really sick or injured	30	2.14	1.04	23	2.08	.99
16	My parent(s) split up	7	1.91	1.31	5	2.38	1.63

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17	I did well in an important test or exam	80	5.68	.63	83	5.54	.74
18	My parent(s) lost their job	4	2.44	1.45	6	2.67	1.52
19	I broke up with a boyfriend or girlfriend	20	3.06	1.53	21	2.72	1.32
20	I had a big argument with someone special to me (who is <u>not</u> in your family)	37	1.84	1.05	35	2.01	1.21
21	I made a special new friend	63	5.48	.79	57	5.53	.85
22	I saw something bad happen (e.g., car accident, someone being robbed)	24	1.74	.86	19	2.09	1.04
23	I changed schools	41	4.91	1.13	8	4.05	1.62
24	Someone in my family died	30	1.42	.80	29	1.52	.97
25	People in my family had a big fight or argument (<u>not</u> including me)	33	1.83	.90	41	2.01	.97
26	My mum got married, engaged or began seeing someone else	7	3.73	1.81	6	4.50	1.53
27	Someone broke into my house	5	2.04	.93	4	2.29	1.15
28	Someone in my family left home	8	2.43	1.52	11	2.98	1.26
29	I was in a fight (<u>not</u> with people in my family)	22	2.54	1.18	20	2.67	1.22
30	I did badly in an important test or exam	50	1.84	.82	60	1.99	.95
31	Someone special to me died (who is <u>not</u> in your family)	12	1.28	.60	10	1.57	.94
32	I was chosen to be class monitor, prefect or school captain	33	5.33	.87	22	5.02	1.02
33	I was seriously told off or punished by a teacher	24	2.43	1.21	24	2.38	.99
34	I took up a new hobby, sport or activity	67	5.37	.74	57	5.36	.72
35	I found out I have to repeat a grade in school	2	3.10	1.60	1	3.14	2.19
36	Someone special to me was really sick or injured (who is not in your family)	19	1.76	.87	16	1.78	1.06
37	My dad got married, engaged or began seeing someone else	7	3.63	1.86	8	3.24	1.77

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38	I went on a special holiday (e.g., overseas, around the UK)	78	5.71	.69	79	5.67	.71
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Individual items at Wave 1 predicting Depression at Wave 1

A regression analysis was conducted including all items at Wave 1 predicting Depression at Wave 1. The model was significant overall, $F(38, 462) = 5.56, R^2 = .31, p < .001$. Three items predicted increasing levels of Depression: *item 12* “I was teased or bullied” ($\beta = .19, t = 4.33, p < .001$), *item 14* “I had a big argument with someone in our family” ($\beta = .19, t = 4.10, p < .001$) and *item 20* “I had a big argument with someone special to me (who is not in your family)” ($\beta = .17, t = 3.85, p < .001$).

Individual items at Wave 2 predicting Depression at Wave 2

A regression analysis was conducted including all items at Wave 2 predicting Depression at Wave 2. The model was significant overall, $F(38, 329) = 4.35, R^2 = .34, p < .001$. One item predicted increasing levels of Depression: *item 14* “I had a big argument with someone in our family” ($\beta = .25, t = 4.69, p < .001$). Two items predicted decreasing levels of Depression: *item 2* “I won a prize, award or contest” ($\beta = -.17, t = -3.35, p < .001$) and *item 38* “I went on a special holiday (e.g., overseas, around the UK)” ($\beta = -.17, t = -3.38, p < .001$). These positive events were highly normative in our sample (both $> 70\%$), therefore the absence of these positive events could indicate abnormal levels of opportunities, e.g., low socioeconomic status, which could be a secondary factor explaining depression.

Appendix B: Factor structure of the Highly Sensitive Child Scale (HSCS)**Table 1.** Factor loadings based on Principal Components Analysis (PCA) with Varimax rotation for 12 items from the HSCS ($N = 424$)

<i>Item</i>	<i>Factor 1</i>	<i>Factor 2</i>	<i>Comm.</i>
2 Some music can make me really happy	.80		.64
11 I don't like it when things change in my life	.74		.56
8 I love nice smells	.71		.56
9 I don't like watching TV programs that have a lot of violence in them	.69		.49
12 When someone observes me, I get nervous. This makes me perform worse than normal	.67		.47
4 Loud noises make me feel uncomfortable	.55		.49
6 I notice it when small things have changed in my environment	.48		.46
10 I don't like loud noises		.78	.61
3 I love nice tastes		.78	.60
5 I am annoyed when people try to get me to do too many things at once		.69	.48
7 I get nervous when I have to do a lot in little time		.41	.17
1 I find it unpleasant to have a lot going on at once		.38	.27

Note: *Comm.* = *Communality*; *Factor loadings* < .30 were suppressed.

Table 2. Descriptive statistics for the two HSCS factors ($N = 424$)

	<i>No. of items</i>	<i>M (SD)</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>Cronbach α</i>
Factor 1	7	4.04 (1.70)	-.04	-.29	.83
Factor 2	5	4.82 (.84)	-.70	1.72	.53

Key points (Appendix B)

- A PCA on the HSCS found two components which explained 48% of total variance (Table 1).

4. SPS in Adolescence

- Item 7 (“I get nervous when I have to do a lot in little time”) showed low communality with the rest of the scale, suggesting it may not be a specific construct related to SPS in adolescents.
- Table 2 displays the descriptive statistics for the factors. Factor 1 showed good internal consistency (Cronbach’s $\alpha = .83$), whereas Factor 2 showed poor internal consistency (Cronbach’s $\alpha = .53$).

Appendix C: Testing procedure for the CogBIAS longitudinal study**Table 1.** List of measures taken at Wave 1 ($N = 504$) and Wave 2 ($N = 450$)

Session 1	Session 2
<i>Cognitive tasks</i>	<i>Cognitive tasks</i>
Flanker task	Memory bias task
Emotion dot-probe task	Balloon Analogue Risk Task (BART)
Interpretation bias task	Food approach/avoidance task
<i>Questionnaires</i>	<i>Questionnaires</i>
Self-esteem	Sensory-Processing Sensitivity (SPS)
Worry	Impulsivity
Anxiety & Depression	Behavioural Inhibition/Activation
Peer victimisation	Risk taking
Life events	Eating behaviour
Rumination	Wellbeing
Pain questionnaires	Resilience

Note: SPS was only assessed once at Wave 2; Saliva samples were also collected at Wave 1 for DNA analysis which will be reported elsewhere; each session took 1 hour to complete and a break was offered in between.

Appendix D

Supplementary analyses

SPS factors

We followed up the significant interaction between SPS and Negative Life Events (NLE) predicting depression at Wave 2 with supplementary analyses, using the separate factors of SPS (i.e., EOE, LST, and AES) as the moderator variable. Results from the three regression models are presented in **Table 1**. All factors predicted increasing levels of depression, therefore high levels represented risk factors overall. Only EOE and LST interacted with NLE, which was followed up with Regions of Significance (RoS) analysis. **Figure 1** depicts these interactions, which showed that high levels of each factor reflected heightened sensitivity to NLE predicting a greater increase in depression symptoms, supporting a diathesis-stress model.

Table 1. *Supplementary analyses showing regression models for SPS factors (EOE, LST, and AES) and Negative Life Events (NLE) predicting depression at Wave 2 (N = 450).*

<i>1) NLE x EOE on depression: $F(5,417) = 20.32, R^2 = .19, p < .001$</i>				
	β	<i>SE</i> β	<i>t</i>	<i>p</i>
Constant	-.91	1.47	-0.61	.539
NLE	.28	.04	6.44	.000
EOE	.21	.04	4.67	.000
NLE x EOE	.10	.04	2.32	.021
<i>2) NLE x LST on depression: $F(5,417) = 22.02, R^2 = .20, p < .001$</i>				
	β	<i>SE</i> β	<i>t</i>	<i>p</i>
Constant	-1.24	1.45	-0.85	.394
NLE	.26	.04	5.95	.000
LST	.23	.04	5.44	.000
NLE x LST	.08	.04	1.98	.048
<i>3) NLE x AES on depression: $F(5,417) = 29.93, R^2 = .26, p < .001$</i>				
	β	<i>SE</i> β	<i>t</i>	<i>p</i>
Constant	-.08	1.41	-0.05	.955
NLE	.25	.04	5.79	.000
AES	.34	.04	8.00	.000
NLE x AES	.06	.04	1.56	.118

4. SPS in Adolescence

Note: NLE = Negative Life Events; EOE = Ease of Excitation; LST = Low Sensory Threshold; AES = Aesthetic Sensitivity; Gender and age were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance.

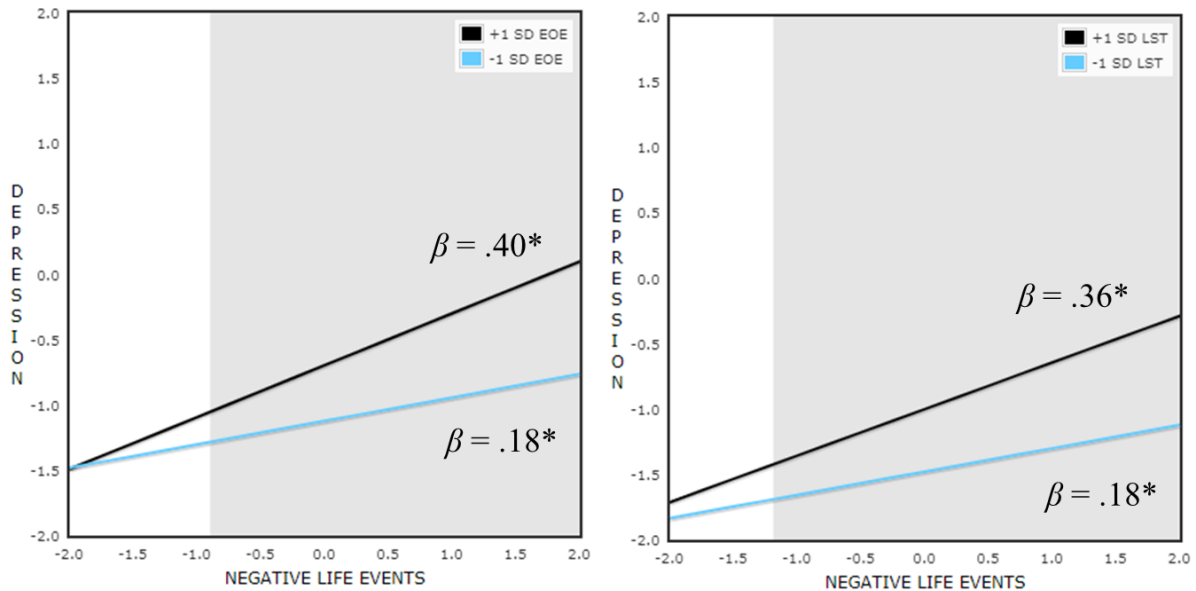


Figure 1. Supplementary analyses showing Regions of Significance (RoS) for all significant interactions between the SPS factors (i.e., EOE, and LST) and negative life events predicting depression at Wave 2; **Note:** Grey area denotes RoS on X; Slope depicted at high (+1 SD) and low (-1SD) for each factor; *Significant at the $p < .05$ level.

Wellbeing subscales

We then analysed the interaction between SPS and NLE predicting each wellbeing subscale, as the model using the total wellbeing score almost reached significance. Results from three regression models are presented in **Table 2**. SPS predicted psychological and social wellbeing overall, but did not interact with NLE in these models. SPS did not predict emotional wellbeing overall, but did interact with NLE in this model, which is depicted in **Figure 2**. At low SPS, NLE had no effect on emotional wellbeing, thus reflecting environmental resistance. At high SPS, increasing NLE predicted decreasing emotional wellbeing, thus reflecting heightened environmental sensitivity, supporting a diathesis-stress model.

4. SPS in Adolescence

Table 2. Supplementary analyses showing regression models for SPS and NLE predicting each wellbeing subscale at Wave 2 (N = 450).

1) NLE x SPS on <i>emotional</i> wellbeing: $F(5,415) = 4.84, R^2 = .05, p < .001$				
	β	SE β	t	p
Constant	.73	1.62	0.44	.653
NLE	-.14	.05	-2.82	.005
SPS	-.08	.05	-1.74	.082
NLE x SPS	-.11	.05	-2.25	.025
2) NLE x SPS on <i>psychological</i> wellbeing: $F(5,415) = 3.80, R^2 = .04, p = .002$				
	β	SE β	t	p
Constant	.52	1.64	0.32	.748
NLE	-.07	.05	-1.50	.134
SPS	-.12	.05	-2.43	.015
NLE x SPS	-.09	.05	-1.83	.067
3) NLE x SPS on <i>social</i> wellbeing: $F(5,415) = 9.19, R^2 = .10, p < .001$				
	β	SE β	t	p
Constant	.87	1.59	0.55	.581
NLE	-.11	.04	-2.26	.024
SPS	-.11	.04	-2.43	.015
NLE x SPS	-.06	.04	-1.29	.195

Note: NLE = Negative Life Events; SPS = Sensory Processing Sensitivity; Gender and age were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance.

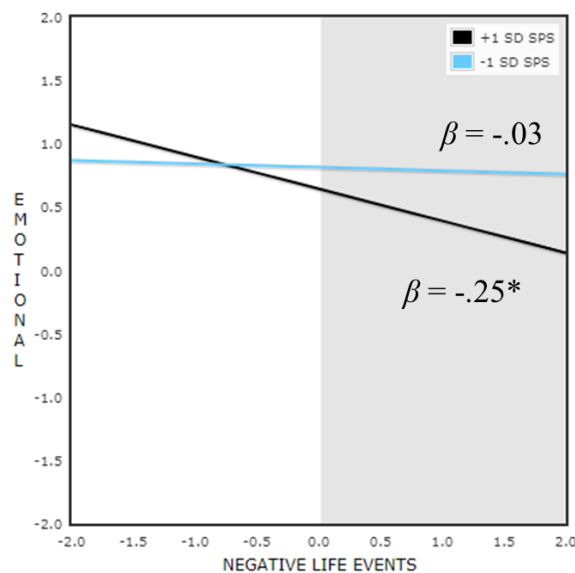


Figure 2. Regions of Significance (RoS) for interaction between SPS and NLE predicting emotional wellbeing; **Note:** Grey area denotes RoS on X; Slope depicted at high (+1 SD) and low (-1SD) SPS; *Significant at the $p < .05$ level.

SPS residualised scores

SPS residualised for the shared variance with wellbeing was used to test the effect of both NLE and PLE on depression at Wave 2. Then the reverse was conducted, whereby SPS residualised for the shared variance with depression, was used to test the effect of both NLE and PLE on wellbeing at Wave 2. **Table 3** presents the results from these four regression models. The interaction was only significant in the model of SPS and NLE predicting depression, which was the same as found in the non-residualised models. **Figure 3** depicts this interaction. At high SPS, the effect of increasing NLE on increasing depression was greater than at low SPS, supporting a diathesis-stress model.

Table 3. *SPS residualised scores moderating effect of NLE and PLE on wellbeing and depression at Wave 2 (N = 450)*

<i>1) NLE x SPS (resid:wellbeing) on depression: $F(5,415) = 20.50, R^2 = .19, p < .001$</i>				
	β	SE β	<i>t</i>	<i>p</i>
Constant	-.83	1.49	-0.56	.575
NLE	.27	.04	6.04	.000
SPS (resid)	.21	.04	4.78	.000
NLE x SPS	.11	.04	2.43	.015
<i>2) PLE x SPS (resid:wellbeing) on depression: $F(5,415) = 10.28, R^2 = .11, p < .001$</i>				
	β	SE β	<i>t</i>	<i>p</i>
Constant	-1.03	1.56	-0.66	.510
PLE	.05	.05	1.04	.296
SPS (resid)	.23	.04	4.94	.000
PLE x SPS	-.01	.05	-0.25	.796
<i>3) NLE x SPS (resid:depression) on wellbeing: $F(5,415) = 5.93, R^2 = .06, p < .001$</i>				
	β	SE β	<i>t</i>	<i>p</i>
Constant	1.62	1.61	1.00	.316
NLE	-.13	.04	-2.74	.006
SPS (resid)	.08	.04	1.66	.097
NLE x SPS	-.08	.05	-1.66	.097
<i>4) PLE x SPS (resid:depression) on wellbeing: $F(5,415) = 4.86, R^2 = .05, p < .001$</i>				
	β	SE β	<i>t</i>	<i>p</i>
Constant	1.61	1.62	0.99	.320
PLE	.12	.05	2.33	.020
SPS (resid)	.10	.04	2.05	.040
PLE x SPS	.017	.04	0.35	.723

Note: *NLE = Negative Life Events; PLE = Positive Life Events; SPS = Sensory Processing Sensitivity; Gender and age were controlled for in all models; Predictor and outcome variables were standardised in line with Regions of Significance; SPS was residualised for the shared variance with both wellbeing and depression in each respective model.*

4. SPS in Adolescence

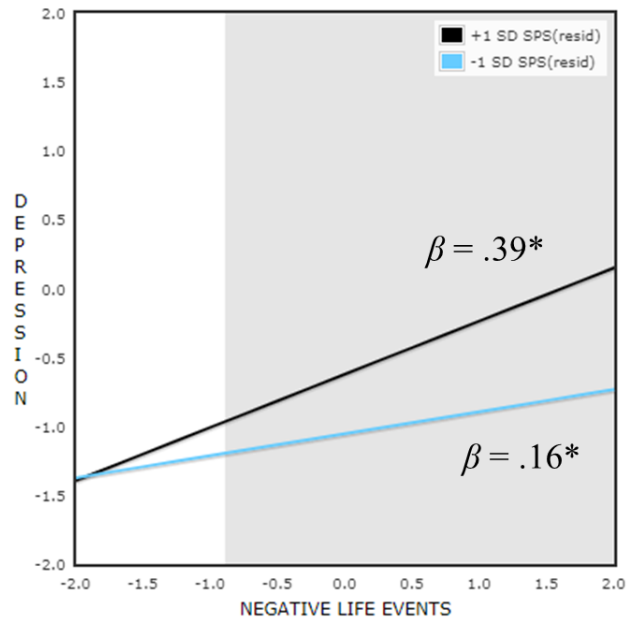


Figure 3. *Supplementary analyses showing Regions of Significance (RoS) for interaction between SPS residualised for wellbeing and NLE on depression. Note: Grey area denotes RoS; Slope depicted at high (+1 SD) and low (-1SD) SPS.*

Chapter 5

5

Is Sensory- Processing Sensitivity associated with enhanced Statistical Learning?

Abstract: Differential susceptibility theory predicts that highly sensitive individuals are more responsive to the environment, due to a general mechanism reflecting increased environmental sensitivity. Sensory-Processing Sensitivity (SPS) is a trait theory of environmental sensitivity, which may reflect differential susceptibility. Statistical learning describes an elementary mechanism aiding the processing of statistical regularities in the environment, which is necessary for adaptive functioning. This study investigated whether high SPS individuals display greater statistical learning on a basic cognitive task, known as the Contextual Cueing (CC) paradigm, which is a visual implicit statistical learning task. In *Study One* ($N = 58$), using an extreme group sampling approach, no differences between high and low SPS groups were observed on the CC task. In *Study Two* ($N = 79$), using a random sampling approach, no association was observed between SPS and performance on the CC task. Therefore, both studies found no association between SPS and statistical learning. However, methodological issues with the task may have explained these results, as the basic CC effect was elusive, despite the task matching previous paradigms. More research is needed to explore possible cognitive mechanisms associated with heightened environmental sensitivity.

Introduction

Sensory-Processing Sensitivity (SPS) describes a fundamental trait difference observed across the human population. The concept was developed to provide an empirical understanding of the colloquial term ‘sensitive’ (Aron & Aron, 1997). SPS is a theory of environmental sensitivity, which describe individual differences within a population that increase responsiveness to the environment, as highly sensitive individuals are expected to show extreme outcomes in response to different contextual conditions (Pluess, 2015a). A related theory, known as differential susceptibility, predicts that highly sensitive individuals are likely to display better than expected outcomes in response to supportive conditions and worse than expected outcomes in response to unsupportive conditions, due to a general mechanism of heightened environmental sensitivity (Belsky, 1997, 2005). This notion of general sensitivity – to positive *and* negative experiences – has been supported in studies assessing moderation effects of different genetic and trait factors on the effect of the environment (e.g., parental support in childhood) on some outcome (e.g., psychological wellbeing) (Belsky & Pluess, 2009). While such studies provide evidence that traits of increased environmental sensitivity exist in the population, little research has explored the underlying mechanisms which might support this. Understanding the mechanisms of environmental sensitivity has been described as a major goal of research on differential susceptibility (Ellis & Boyce, 2011).

SPS describes a rich and multifaceted concept reflecting environmental sensitivity (Aron et al., 2012). Four broad attributes are often used to describe SPS including: (i) sensitivity to environmental subtleties, (ii) behavioural inhibition in novel situations, (iii) engagement in deeper cognitive processing strategies, and (iv) heightened emotional reactivity. Those high on the trait are thought to be able to use these attributes to their advantage, e.g., by pursuing pathways that others may fail to notice, such as finding short-

cuts to avoid traffic jams (Aron et al., 2012). SPS is measured by self-report with the *Highly Sensitive Person Scale* (HSPS: Aron & Aron, 1997), which was originally considered as a unidimensional measure, however later psychometric evaluations found a three factor structure (Smolewska et al., 2006). The three factors correspond to (i) *Ease of Excitation* (EOE), which relates to becoming overwhelmed by increasing stimulation, (ii) *Low Sensory Threshold* (LST), which relates to unpleasant arousal in response to sensory input, and (iii) *Aesthetic Sensitivity* (AES), which relates to an appreciation for the subtleties and beauty of the surrounding environment. EOE and LST have been shown to associate with more negative outcomes, such as neuroticism and negative affect, whereas AES has been shown to correlate with more positive outcomes, such as openness to experience and positive affect (Pluess et al., 2018; Smolewska et al., 2006; Sobocko & Zelenski, 2015). Despite these differences, SPS is generally regarded as a unidimensional construct, assessed with the HSPS total score (Aron et al., 2012).

Research on SPS has mainly focused on its association with other self-reported psychological constructs (Hofmann & Bitran, 2007; Liss et al., 2008; Smolewska et al., 2006; Sobocko & Zelenski, 2015) and its potential as a moderator of environmental experience (Booth et al., 2015; Liss et al., 2005; Pluess & Boniwell, 2015). Little research has been conducted on its association with cognitive behavioural measures, which could help to explain the mechanisms underlying environmental sensitivity. One previous study examined SPS in relation to performance on a standard visual search task (Gerstenberg, 2012). In this study, participants were asked to distinguish between targets (a letter “T”) and distractors (letter “L”s), and respond to whether targets were present or absent as fast and accurately as possible, over 120 experimental trials with varying levels of difficulty. It was found that those scoring highly on the HSPS made fewer errors and were faster to respond across trials. This was the case for the total score and for each of the sub-factors, however it was suggested that

only LST predicted unique variance in task performance. Personality was also assessed using the Big Five (Costa & MacCrae, 1992) and task performance was unrelated to any of these personality factors. This study suggests that high SPS individuals are more sensitive to noticing visual changes or subtleties, which has also been supported in a previous fMRI study using a change detection task (Jagiellowicz et al., 2011). However, this previous research requires replication before drawing any firm conclusions. Further, it is possible that high SPS participants responded faster and made fewer errors due to increased attention or motivation to perform well, as opposed to greater awareness of environmental subtleties. Using a similar task with built-in contingencies to differentiate between trials that have been processed more deeply, at an implicit level, with unlearned trials will provide better insight into whether high SPS individuals are better at noticing subtleties and process information at a deeper level. Theory suggests that high SPS individuals “might also have more rapid and efficient unconscious processing, commonly called intuition” (Aron et al., 2012, p.267), therefore assessing performance on an implicit task of unconscious processing may be particularly informative.

Statistical learning is described as an elementary learning mechanism that enables people to learn from repeated patterns in the environment (Goujon, Didierjean & Thorpe, 2015). It is an adaptive cognitive mechanism that allows the detection of statistical regularities in the environment, which enables more accurate prediction of events in the near future (Ludwig, Farrell, Ellis, Hardwicke, & Gilchrist, 2012). It is thought to be crucial for many areas of learning, including language acquisition, object recognition, scene identification and area navigation (Goujon, Didierjean, & Thorpe, 2015). Statistical learning is elegantly captured by Contextual Cueing (CC) paradigms (Chun & Jiang, 1998), which require participants to view search arrays and find a target letter “T” hidden amongst distractor “L”s that are rotated randomly in different orientations. The crucial element of the

task is that half of the search arrays are repeatedly presented in every block – termed “old” trials – whilst the other half are random configuration search arrays – termed “new” trials. Over time, participants are expected to respond faster to old trials, as the repeated distractor configurations are thought to cue the localisation of the target. This task is ideal for measuring implicit visual statistical learning and could be used in the field of individual differences, to assess mechanisms associated with environmental sensitivity. Given that high SPS individuals are thought to be more sensitive to environmental subtleties and engage deeper cognitive processing strategies at an implicit level, we expect that high SPS will be related to greater statistical learning, assessed with the CC task. This would reflect a learning mechanism, related to differential susceptibility theory, i.e., heightened sensitivity to the environment in a general way.

A recent study set out to answer the question of what drives the CC effect (Bellaera, von Mühlennen, & Watson, 2014). The original theory, known as the ‘configural learning account’ (Chun & Jiang, 1998; Chun & Phelps, 1999), posited that the overall global search array in old trials cued the position of the target. However, more recent research has proposed that more localised cues (spatially near to the target) are more important for CC, which has been termed the ‘subset account’ (Hoffman & Sebold, 2005; Olson & Chun, 2002). Bellaera and colleagues (2014) set out to test this using an individual differences approach, by assessing the correlation between global/local (GL) attention bias and CC effect. The CC task included 4 epochs of 102 search arrays each (50% old trials, 50% new trials). They observed a CC effect during epoch 3, as old trials were responded to significantly faster than new trials. They calculated a CC effect score for each participant by subtracting mean reaction time (RT) for old trials from mean RT for new trials in the second half of the task (epochs 3 and 4). They found a moderate negative correlation between global attention bias and CC effect ($r =$

-.56, $p < .001$), suggesting that participants with more of a local attention bias showed enhanced statistical learning, supporting the subset account.

Given that local attention bias is associated with enhanced CC and that we predict that high SPS will be associated with enhanced CC, we expect that high SPS will also be associated with local attention bias. There is further reason to expect a relationship between SPS and GL attention bias, which is related to mood. Processing visual information at the global level – i.e. “seeing the forest before the trees” – was thought to be the default mode in humans (Navon, 1977). However, decades of research have revealed vast individual differences in GL processing – specifically that some individuals are more likely to show a local attention bias – i.e., “seeing the trees before the forest” – which has been observed in high trait anxious individuals (Tyler & Tucker, 1982), in children and adolescents in comparison to adults (Scherf, Behrmann, Kimchi, & Luna, 2009), in autism (Koldewyn, Jiang, Weigelt, & Kanwisher, 2013) and in individuals displaying dysphoria, high anxiety, and low optimism (Basso, Schefft, Ris, & Dember, 1996). The “affect-as-information” model proposes that mood is the key factor in guiding information processing of the environment (Martin, Ward, Achee, & Wyer, 1993; Schwarz & Clore, 1983) – specifically that negative mood promotes analytical processing of details in the environment, while positive mood promotes heuristic strategies focusing on the “big picture”. This can be understood as a flexible and adaptive mechanism, as negative mood, such as anxiety primes threat detection, whilst positive mood promotes a safety bias (Tan, Jones, & Watson, 2009). High SPS is consistently associated with low mood (Booth et al., 2015; Liss et al., 2005), which could drive an association with local attention bias.

The aim of the current study was to test the association between SPS and performance on the CC task and the GL task. We expected that high SPS would be associated with greater statistical learning, as evidenced by a larger CC effect, as well as more of a local attention

bias. We wanted to assess SPS in relation to these basic non-emotional tasks, based on the background research regarding environmental sensitivity and differential susceptibility in particular, which posits that certain traits render individuals more sensitive to the environment in a general way. We measured levels of depression, in order to be able to control for this against task performance.

Study One

Hypotheses

1. High SPS individuals will report lower mood, as indicated by higher depression, anxiety and perceived stress scores.
2. High SPS individuals will show greater statistical learning, as evidenced by a larger CC effect score.
3. High SPS individuals will show more of a local attention bias.
4. Local attention bias will be related to larger CC effect scores in line with the subset account.

Methods

Participants

Participants were recruited from two participant-pools – one designed for undergraduate psychology students to receive course credit and another wider community group who were paid for participation. A total of 188 participants were screened using the 27-item Highly Sensitive Person Scale (HSPS: Aron & Aron, 1997) and were invited into the laboratory if they scored less than 3.7 or more than 4.7, which represented 1 *SD* below the mean and 1 *SD* above the mean based on a previous study (Booth et al., 2015). Further inclusion criteria included being aged between 18 and 35, not currently suffering with any mental health

disorder, or no known neurological condition. We tested 58 participants, aged between 18 and 33 (*mean age* = 21.81, *SD* = 4.21). Participants were mostly right-handed (88%) and female (66%). One participant performed at chance-level accuracy on the CC task and was excluded from further analysis. The final sample included 29 high SPS and 28 low SPS individuals.

Measures

Questionnaires

Highly Sensitive Person Scale (HSPS: Aron & Aron, 1997). The HSPS is a 27-item scale designed to measure SPS. For the current study we used the HSPS as a pre-screening measure to distinguish high and low SPS participants. Participants were asked to answer each item on a 7-point scale from 1 (“Not at all”) to 7 (“Extremely”). Scores were calculated for each participant by averaging the total score, thus scores could range from 1 – 7. Individuals scoring below 3.7 were considered low SPS and individuals scoring above 4.7 were considered high SPS (Booth et al., 2015). Internal consistency for the scale was excellent (Cronbach’s $\alpha = .94$).

Beck Depression Inventory second edition (BDI-II: Beck, Steer & Brown, 1996). The BDI-II is a 21-item scale designed to measure depression severity. Each item represents a different symptom of depression (e.g., “Sadness”, “Pessimism”, “Loss of pleasure”, “Guilty feelings”, “Loss of energy”, “Loss of appetite”). Participants were asked to rate the presence of each symptom during the past 2 weeks using a 4-point scale from 0 (“Never”) to 3 (“All the time”). Items were summed and scores could range from 0 – 63. Scores between 0-13 are considered in the normal range; 14-19 indicates mild depression; 20-28 is moderate and 29-63 is severe. The BDI-II is a well validated and reliable measure of depression. Internal consistency was excellent (Cronbach’s $\alpha = .91$).

State-Trait Anxiety Inventory (STAI: Spielberger, Gorsuch, & Lushene, 1970). The STAI is a 40-item anxiety inventory split into two scales designed to assess state and trait anxiety. The STAI-*State* asks participants to answer 20-items according to how they feel in the present moment (e.g., “calm”, “tense”, “jittery”, “satisfied”) using a 4-point scale from 1 (“Not at all”) to 4 (“Very much so”). The STAI-*Trait* contains very similar items (e.g., “pleasant”, “nervous” or “restless”), yet participants are asked to respond according to how they “generally feel”. The STAI is a widely used measure of anxiety with good psychometric properties. Both scales were summed and can range from 20 to 80. Internal consistency was excellent (Cronbach’s $\alpha = .94$ and $\alpha = .94$ respectively).

Perceived Stress Scale (PSS: Cohen, Kamarck, & Mermelstein, 1983). The PSS is a 10-item scale designed to measure the perception of stress – specifically how unpredictable, uncontrollable and overloaded respondents find their life experiences. It is a measure of how stressful events are appraised, rather than frequency of stressful events (e.g., “In the past month, how often have you been upset because of something that happened unexpectedly?”, “In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?”). Participants were asked to respond using a 5-point scale from 0 (“Never”) to 4 (“Very often”). Scores were summed and could range from 0 to 40. The PSS is a widely used psychological measure and has good psychometric properties. Internal consistency was excellent (Cronbach’s $\alpha = .91$).

Behavioural measures

Contextual Cueing (CC) task

We administered a standard CC task (Bellaera et al., 2014) programmed in *Inquisit* software. Participants were instructed to respond to a target letter – “T” – which was titled 90 degrees left or right, by pressing the strict inequality symbols on the keyboard (“<” = left;

“>” = right). Target letters were presented in an invisible 8 by 6 matrix (cell size 3.50° - random jitter up to 0.5°) with 12 distractor letter “L”s – rotated randomly by 0, 90, 180 or 270 degrees. We included one extra distractor letter than previous authors after testing 8 pilot participants and finding that the CC effect appeared as early as epoch one, therefore our aim was to increase task difficulty with an extra distractor. Each letter was 0.67° in visual angle, and the vertical line of the “L” was shifted 0.13° to the right (see **Figure 1**). Stimuli were grey (RGB values: 128, 128, 128) presented on a black background. Participants completed 16 blocks (24 trials in each). The main independent variable was trial type (old vs. new) – 12 search arrays were created for each participant randomly and presented once in every block (old trials) – the other 12 search arrays in each block were random and not repeated (new trials). In old trials, distractor orientation was fixed, however target orientation (90 degrees left or right) was random, so that motor response was not learnt. In new trials, distractor position was random, however target position (not orientation) was fixed to 12 positions, to rule out location probability effects. Trials started with a fixation cross (750ms), followed by a blank screen (250ms), followed by a search array (until response). To increase power, blocks were grouped into 4 epochs (consisting of 4 blocks each). A CC effect score was calculated by subtracting mean RT for old trials from mean RT for new trials, in all correct trials during epochs 3 and 4.

Unfortunately, we discovered an error in our script after testing was completed, which caused distractor orientations in old trials to be fixed at 270 degrees – this meant that old trials were perceptually easier than new trials, therefore targets were easier to find in old trials (before any statistical learning took place), which explained why we appeared to observe the CC effect as early as epoch one during the piloting phase.

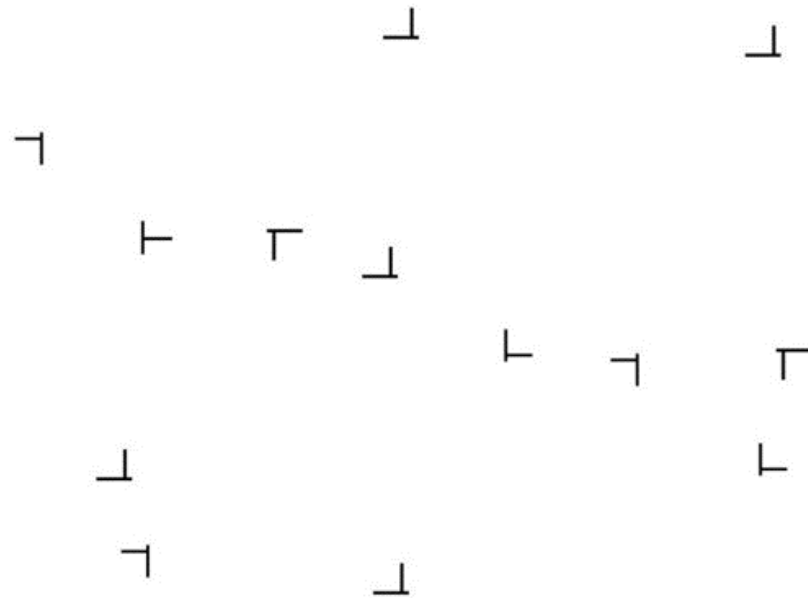


Figure 1. *Schematic of search array from the contextual cueing task*

Global-local (GL) task

We administered a shape detection task to assess degree of global attention bias (Bellaera et al., 2014) programmed in *Inquisit*. Stimuli comprised larger “global” shapes made up of smaller “local” shapes. Shapes were equilateral triangles, squares, circles and diamonds – global and local shapes were always different for each trial (see **Figure 2**). Global shapes were 3.63° in visual angle, while local shapes were 0.48° . Stimuli were grey (RGB values: 128, 128, 128) presented on a black background. There were four blocks (24 trials each) and each of the 12 stimuli were presented twice in each block. Participants were instructed to respond to a particular shape target – ignoring whether the shape was presented at the global or local level – and the target shape changed for each block (i.e., each shape was the target once). They were instructed to press “Z” if the target shape was present in the trial and press “M” if the target shape was absent in the trial (counterbalanced across participants).

Targets were absent in 50% of trials and when present were equally likely to be presented at the global or local level (25% of trials each). A fixation cross was presented (750ms), followed by a blank screen (250ms), followed by the trial (until response). A global attention bias score was calculated by subtracting mean RT for local trials from mean RT for global trials for correct trials only. Positive scores reflect a global bias and negative scores reflect a local bias.

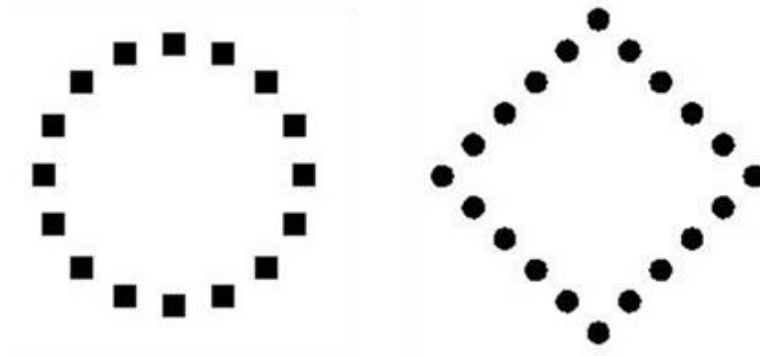


Figure 2. *Schematic of two trials from the global-local task. Figure on left shows squares at the local level and circle at the global level. Figure on right shows circles at the local level and diamond at the global level.*

Procedure

Participants who met the inclusion criteria completed testing at the Department of Experimental Psychology, University of Oxford. They were seated in a dimly lit quiet testing cubicle approximately 60cm from the computer screen, which was a Dell (P2414H) with 1920 x 1080 resolution. They were asked to follow the on-screen instructions for each of the tasks – first completing the GL task and then completing the CC task. After the tasks were completed participants completed the questionnaires. The test session was completed in less

than one hour, after which participants were thanked, debriefed and either paid £10 or received course credit.

Statistics

We conducted repeated measures ANOVAs for both the CC task and the GL task, to assess task performance and to test for any between-group differences. We then conducted between-group comparisons by either independent samples t-tests or Chi-square tests for all the self-report measures and behavioural indices from the tasks.

Results

Contextual Cueing Results

Incorrect trials were removed from further analysis (3.7%). We also removed RTs that were 3 *SDs* from each participants mean for old trials (0.9%) and new trials (1%) respectively. We then conducted a 2 (SPS group: low vs. high) x 2 (trial type: old vs. new) x 4 (epoch: 1, 2, 3, 4) repeated measures ANOVA. We found a main effect of trial type, $F(1, 55) = 787.24, p < .001, \eta^2 = .94$, as old trials ($M = 1593\text{ms}$) were responded to faster than new trials ($M = 2796\text{ms}$), which was expected, however this difference was inflated due to the nature of the error in the orientation of distractors in old trials. We also found a main effect of epoch, $F(3, 165) = 87.08, p < .001, \eta^2 = .61$. Post-hoc pairwise comparisons with Least Significance Difference (LSD) correction showed that there was a linear decrease in RT with each epoch, $F(1, 55) = 200.26, p < .001, \eta^2 = .79$. We found an interaction between trial type and epoch, $F(3, 165) = 2.77, p = .040, \eta^2 = .05$. We followed this up by conducting two further repeated measures ANOVAs for each trial type separately. This revealed that the effect of epoch was greater for old trials, $F(3, 168) = 126.72, p < .001, \eta^2 = .82$, than for new trials, $F(3, 168) =$

39.98, $p < .001$, $\eta^2 = .42$, suggesting that some degree of statistical learning occurred for old trials. We failed to find a significant interaction between trial type and SPS group, $F(1, 55) = 1.49$, $p = .231$, $\eta^2 = .03$, which is depicted in **Figure 3**. We failed to find a significant interaction between epoch and SPS group, $F(3, 165) = 1.60$, $p = .192$, $\eta^2 = .03$. Finally, we failed to find a 3-way interaction between trial type, SPS group and epoch, $F(3, 165) = 1.81$, $p = .154$, $\eta^2 = .03$, therefore no group differences were observed. The pattern of results did not change when we removed participants in the depressed or severely depressed range based on BDI-II scores.

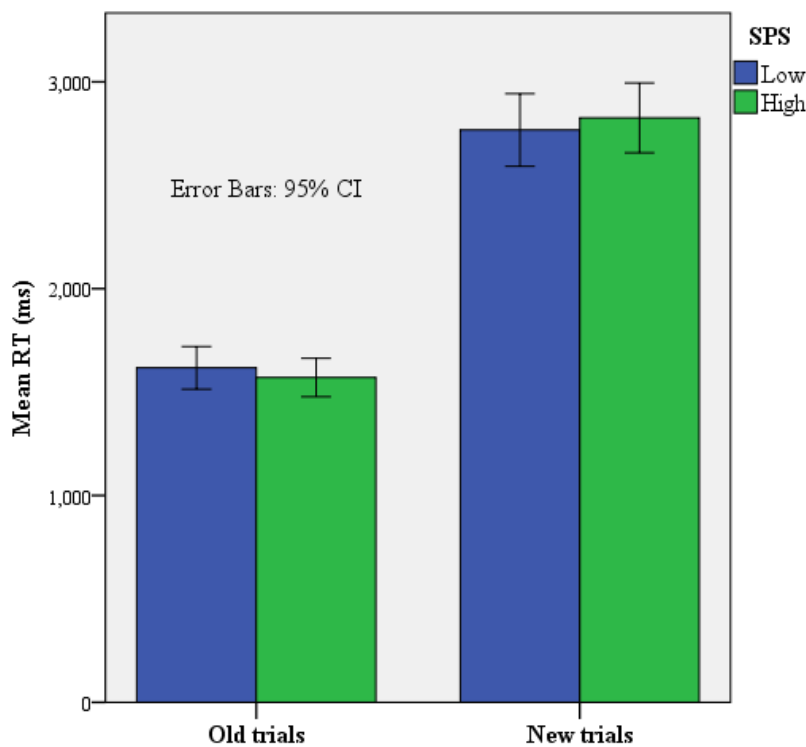


Figure 3. Mean RT (ms) for Old and New trials by SPS group (low and high) on CC task.

Global Local Results

Incorrect trials were removed from further analysis (8.1%). We also removed RTs that were considered extremely fast ($< 200\text{ms}$: 0%) and extremely slow ($> 2500\text{ms}$: 0.2%)

based on previous research (Bellaera et al., 2014). We conducted a 2 (SPS group: low vs. high) x 3 (trial type: global, local, absent) repeated measures ANOVA. We found a main effect of trial type, $F(2, 110) = 58.56, p < .001, \eta^2 = .52$, and post-hoc pairwise comparisons with LSD correction revealed that RT significantly differed in each case. Target absent trials were responded to slowest ($M = 727.86$), followed by local trials ($M = 685.63$) and global trials were responded to fastest ($M = 643.25$). We found no interaction between trial type and SPS group, $F(2, 110) = 0.90, p = .417, \eta^2 = .02$. Tests of between-subjects effects also revealed no main effect of SPS group, $F(1, 55) = 2.00, p = .170, \eta^2 = .04$. Therefore, no group differences were observed on the GL task.

Between-Group Comparisons

Despite failing to find any group differences on the CC task or the GL task in the repeated measures ANOVAs, we still computed bias indices for each task. **Table 1** presents the descriptive statistics and the results for the between group comparisons for all variables measured. No group differences were observed for gender, handedness, age or years of education. Group differences were observed for all mood-related measures, as the high SPS group consistently reported lower mood than the low SPS group. The groups significantly differed on SPS, $t(55) = -16.57, p < .001, d = 4.43$, depression, $t(55) = -2.99, p < .001, d = .80$, state anxiety, $t(55) = -3.13, p < .001, d = .84$, trait anxiety, $t(55) = -4.36, p < .001, d = 1.15$, and perceived stress, $t(55) = -4.46, p < .001, d = 1.18$. We observed no group differences on the CC effect score, $t(55) = -.63, p = .535, d = .17$, nor on the global attention bias index, $t(55) = 1.14, p = .260, d = .30$. The high SPS group made fewer errors on the CC task, $t(55) = -2.37, p = .026, d = .63$, however errors in the GL task were equivalent across groups, $t(55) = -1.40, p = .200, d = .26$.

Finally, we tested the correlation between CC effect score and global attention bias index, but failed to find a significant association, $r = -.20$, $p = .141$.

Table 1. *Descriptive statistics and between group comparisons for Study One*

	High SPS (n = 29)	Low SPS (n = 28)	X^2 / t
Gender (female)	77%	67%	0.72
Handedness (right)	88%	85%	1.12
Age	22.07 (4.43)	21.75 (4.24)	-0.28
Years of education	15.67 (3.04)	15.79 (3.37)	0.14
SPS	5.27 (.39)	3.26 (.51)	-16.57**
Depression	12.55 (10.11)	6.14 (5.17)	-2.99**
State anxiety	42.28 (12.93)	33.37 (7.47)	-3.13**
Trait anxiety	49.38 (12.46)	37.43 (7.58)	-4.36**
Perceived stress	21.48 (6.74)	14.39 (5.13)	-4.46**
CC effect	1183.91 (388.00)	1120.33 (368.84)	-0.63
CC correct trials	.97 (.02)	.95 (.04)	-2.37*
Global attention bias	32.62 (70.48)	52.14 (57.49)	1.14
GL correct trials	.93 (.04)	.91 (.10)	-1.40

Note: SPS = Sensory-Processing Sensitivity; CC = Contextual Cueing; GL = Global Local; Means presented with standard deviations in parentheses; Percentages assessed with Pearson Chi-square test, Means assessed with independent samples t-tests; **Significant at $p < .001$, *Significant at $p < .03$.

Discussion

We found that high SPS was associated with lower mood, indicated by higher depression, anxiety and perceived stress, which supported our first hypothesis. We found that high SPS

was not associated with enhanced statistical learning, which failed to support our second hypothesis. We found that high SPS was not associated with local attention bias, which failed to support our third hypothesis. Finally, we found no correlation between local attention bias and CC effect, which failed to support our fourth hypothesis.

We found that high SPS participants reported elevated levels of depression, anxiety and perceived stress. This is in line with previous research, which suggests that high SPS is a risk factor for low mood, in combination with stressful life events (Booth et al., 2015; Liss et al., 2005). However, the current study suggests that high SPS is a risk factor for low mood regardless of life events. This is problematic for considering high SPS as a trait representing differential susceptibility, which predicts that traits of heightened environmental sensitivity should be uncorrelated with outcomes of interest, due to highly sensitive individuals representing extreme scores on both ends of the outcome continuum (Belsky & Pluess, 2009). However, we did not measure levels of stress in the current study and it is possible that the sample were experiencing high levels of stress, as they were all students tested during term time. We did observe greater variability in mood scores in the high compared to low SPS group, suggesting greater emotional reactivity. Further, the largest difference in mood scores between groups was on levels of perceived stress, which suggests that high SPS individuals are particularly sensitive to stress.

The results from the CC task should be interpreted with caution, given the error in the orientation of distractors in old trials, making these trials easier to perform. Although we were most interested in investigating group differences in CC, it was important to replicate the basic CC effect, which we were unable to do. However, we did observe an interaction between trial type and epoch and follow-up analyses showed that the rate of learning was greater for old trials compared to new trials, suggesting that we did observe some degree of CC. Despite this, we failed to find any group differences on the CC effect score, as high SPS

individuals did not show a greater effect, as we predicted. This suggests that high SPS individuals are not more sensitive to picking up subtle statistical regularities in the environment in a general way, which would have provided a potential cognitive mechanism for heightened environmental sensitivity. However, this result requires replication with a CC task that does not have any perceptual errors, which was the main aim of *Study Two*.

The results from the GL task supported previous research, as participants were generally faster to respond to global trials than local trials, supporting the global attention bias theory (Bellaera et al., 2014; Navon, 1977; Tan et al., 2009). However, we failed to find an association between GL attention bias and CC effect, which did not support previous research (Bellaera et al., 2014). We also found no association between GL attention bias and SPS, as we predicted. This suggests that high SPS individuals do not have a particularly narrow focus of attention. However, we did observe a higher error rate on the GL task than expected based on previous research, therefore we aimed to test these associations once more in *Study Two*, using the same task, but with additional trials to aid practice and performance.

Study Two

The aim of *Study Two* was to repeat the experiment, using an error-free CC task. We decided to run a random samples study, rather than using extreme-groups sampling, in order to test the correlation between SPS and CC effect, as well as local attention bias. We did not attempt to replicate the association between SPS and mood measures, as this has been shown extensively in the literature, however we did measure depression, as severe depression could influence task performance. We wanted to test the association between SPS and GL attention bias, as well as the association between CC and GL attention bias once more, therefore we included the same GL task, however we doubled the number of trials in this task, as we found

a relatively high number of errors in the previous study. We also assessed the factorial structure of SPS in order to test associations between task performance and the components of SPS.

Hypotheses

1. High SPS will be related to greater statistical learning, as evidenced by larger CC effect scores.
2. High SPS will be related to more of a local attention bias.
3. Local attention bias will be related to larger CC effect scores.

Methods

Participants

Participants were 79 individuals who did not participate in *Study One*, but who were recruited using the same online participant databases. The majority of participants were undergraduate psychology students who received course credit for taking part (60%), while the remaining sample were a similar student demographic, but were paid for participation. Inclusion criteria was being aged between 18 and 35, not currently suffering with any mental health disorder or no known neurological condition. Age ranged from 18 – 28 (mean age = 19.82, $SD = 2.44$). Most of the participants were female (82%). One participant was excluded for falling asleep during the CC task. The final sample included 78 individuals.

Measures

Questionnaires

We administered two of the five questionnaires from *Study One* – namely the *Highly Sensitive Person Scale* (HSPS: Aron & Aron, 1997) and the *Beck Depression Inventory second edition* (BDI-II: Beck, Steer & Brown, 1996). The BDI-II was used again to check whether results from the cognitive tasks changed when excluding those in the depressed or severely depressed range. For the HSPS, we also computed scores for the sub-factors of SPS based on previous factor analysis and item loadings (Smolewska et al., 2006), in order to test the correlation between each factor and performance on the cognitive tasks. The three factors are *Ease of Excitation* (EOE), which relates to becoming overwhelmed by increasing stimulation, *Low Sensory Threshold* (LST), which relates to unpleasant arousal in response to sensory input, and *Aesthetic Sensitivity* (AES), which relates to an appreciation for the subtleties and beauty of the surrounding environment.

Behavioural tasks

Contextual cueing (CC) task

We administered the same CC task as *Study One*, however there was no error in the task, as distractor letters were randomly rotated by 0, 90, 180 or 270 degrees for both old and new trials. We concluded in the previous study that old trials were responded to faster from the beginning of the task due to distractor letters being fixed at one orientation, rather than the CC effect occurring too early due, therefore we removed one distractor letter, which we had added for *Study One*, thus the current CC task had 11 distractors and was a direct comparison of previous paradigms (Bellaera et al., 2014).

Global Local (GL) task

We administered the same GL task as *Study One*, however we doubled the number of trials, therefore there were 48 trials in each of the four blocks, and 192 trials in total.

Procedure

Participants who met the inclusion criteria completed testing at the Department of Experimental Psychology, University of Oxford. They were seated in a dimly lit quiet testing cubicle approximately 60cm from the computer screen, which was a Dell (P2414H) with 1920 x 1080 resolution. They were instructed how to perform each of the tasks in detail by the experimenter – first completing the GL task and then completing the CC task. After the tasks were completed, participants completed the questionnaires. The test session was completed in approximately 45 minutes, after which participants were thanked, debriefed and either paid £8 or received course credit.

Statistics

We wanted to test the correlation between SPS and CC effect therefore we did not pre-select high and low SPS participants – however we wanted to run the same analyses as *Study One*, in order to check the tasks worked in the intended way. Therefore, we performed a median split on the sample to create a high and low SPS group to enter into a 2 (SPS group: high, low) x 2 (trial type: old, new) x 4 (epoch: 1, 2, 3, 4) repeated measures ANOVA for the CC task and a 2 (SPS group: high, low) x 3 (trial type: absent, global, local) repeated measures ANOVA for the GL task.

Results

Between-group comparisons

We conducted a median split on the SPS scores, therefore those scoring above 4.17 were considered high SPS ($n = 40$) and those scoring below 4.16 were considered low SPS ($n = 38$). Descriptive statistics and between group comparisons are displayed in **Table 2**. The

groups significantly differed on SPS, $t(76) = -10.64$, $p < .001$, $d = 2.41$. The high SPS group were significantly more depressed, $t(76) = -2.61$, $p = .011$, $d = .59$. The two groups did not differ on the CC effect score, $t(76) = .39$, $p = .703$, $d = .09$, nor on global attention bias index, $t(76) = .65$, $p = .512$, $d = .15$. The two groups did not differ on number of correct trials for the CC task, $t(76) = 1.10$, $p = .301$, $d = .00$, nor for the GL task, $t(76) = -.70$, $p = .502$, $d = .33$.

Table 2. *Descriptive statistics and between group comparisons on SPS groups (created by median split) for study two.*

	High SPS ($n = 40$)	Low SPS ($n = 38$)	t
SPS	4.79 (.50)	3.50 (.57)	-10.64*
Depression	11.73 (9.87)	6.29 (8.45)	-2.61*
CC effect (ms)	77.92 (309.29)	103.64 (273.07)	0.39
CC correct trials	.97 (.04)	.97 (.02)	1.10
Global attention bias	35.64 (41.15)	42.27 (47.95)	0.65
GL correct trials	.95 (.03)	.94 (.03)	-0.70

Note: CC = Contextual Cueing; Means presented with standard deviations in parentheses; Means assessed with independent samples t -tests; *Significant at $p < .01$.

Contextual Cueing Results

Incorrect trials were removed from further analysis (3.1%). We also removed RTs that were 3 SDs from each participants mean for old trials (0.9%) and new trials (0.9%) respectively. We conducted a 2 (SPS group: high, low) x 2 (trial type: old, new) x 4 (epoch: 1, 2, 3, 4) repeated measures ANOVA. We found a main effect of trial type, $F(1,76) = 6.53$, $p = .012$, $\eta^2 = .10$, as old trials ($M = 2649ms$) were found faster than new trials ($M = 2727ms$). We found a main effect of epoch, $F(3,228) = 103.87$, $p < .001$, $\eta^2 = .57$, and post-hoc

pairwise comparisons with LSD correction showed that there was a linear decrease in RT with each epoch, $F(1,76) = 228.34$, $p < .001$, $\eta^2 = .75$. We failed to find an interaction between trial type and epoch, $F(3,228) = 0.39$, $p = .762$, $\eta^2 = .01$, suggesting that we failed to find a CC effect. We ran two separate repeated measures ANOVA for each trial type separately (as in *Study One*). We found that learning rate across epochs was similar for old trials, $F(3,232) = 76.94$, $p < .001$, $\eta^2 = .50$, and new trials, $F(3,231) = 57.36$, $p < .001$, $\eta^2 = .43$, failing to support the CC effect. We did not observe an interaction between SPS group and trial type, $F(1,76) = 0.00$, $p = .985$, $\eta^2 = .00$ (**Figure 4**), nor between SPS and epoch, $F(3,228) = 0.12$, $p = .951$, $\eta^2 = .00$. Finally, we did not observe a three-way interaction between SPS group, trial type and epoch, $F(3,228) = 0.54$, $p = .652$, $\eta^2 = .01$. The pattern of results did not change when participants in the depressed or severely depressed range were excluded.

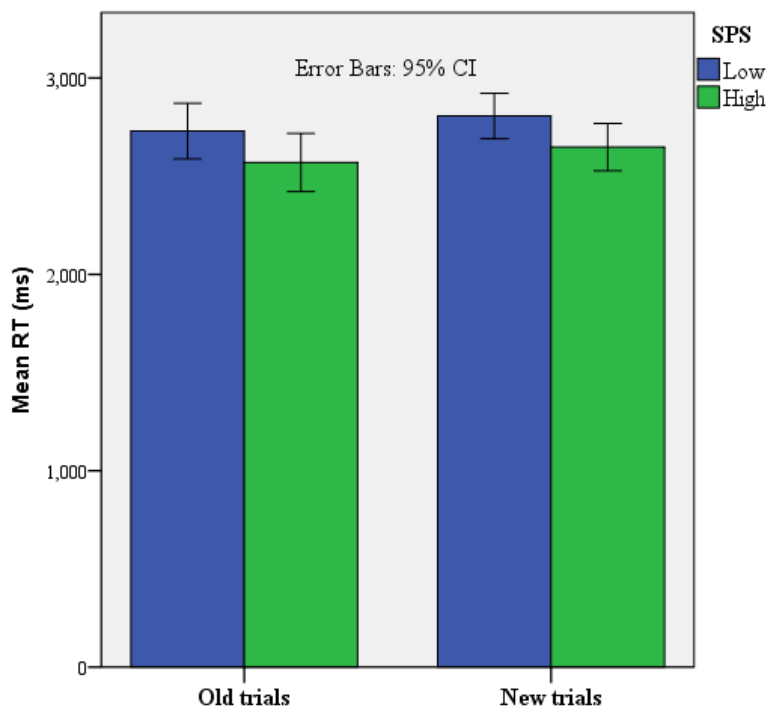


Figure 4. Mean RT (ms) for Old and New trials by SPS group (low and high) on CC task

Global Local Results

Incorrect trials were excluded from further analysis (6.6%), as well as RTs that were extremely fast (< 200ms: 0%) and extremely slow (> 2500ms: 0.2%). We conducted a 2 (SPS group: low, high) x 3 (trial type: global, local, absent) repeated measured ANOVA. We found a main effect of trial type, $F(2,152) = 150.92$, $p < .001$, $\eta^2 = .67$, and post-hoc pairwise comparisons with LSD correction revealed that RT differed in all cases. Target absent trials were responded to slowest ($M = 729.63$), followed by local trials ($M = 675.69$) and global trials were responded to fastest ($M = 636.73$). We failed to find an interaction between trial type and SPS group, $F(2,152) = 0.22$, $p = .802$, $\eta^2 = .00$. Tests of between-subjects effects revealed no main effect of SPS group, $F(1,76) = 0.46$, $p = .501$, $\eta^2 = .01$, therefore no group differences were observed.

Correlations

A correlation table is shown in **Table 3**. SPS correlated highly with each of the sub-factors. However, AES showed the lowest correlation with the total score and the other two factors. SPS correlated positively with depression. While EOE showed a moderate positive correlation with depression, the other factors did not correlate with depression. SPS did not correlate with CC effect, nor global attention bias index. None of the factors correlated with CC effect, nor global attention bias. CC effect and global attention bias were not correlated.

Table 3. *Bivariate correlations between variables in study two (N = 78)*

Variable	1	2	3	4	5	6
1. SPS	-					
2. EOE	.91*	-				
3. LST	.83*	.62*	-			
4. AES	.60*	.40*	.33*	-		
5. Depression	.31*	.35*	.20	-.02	-	
6. CC effect	-.10	-.11	-.10	.10	-.05	-
7. Global attention bias	-.14	-.15	-.10	-.12	-.10	.02

Note: SPS = Sensory Processing Sensitivity, EOE = Ease of Excitation, LST = Low Sensory Threshold, AES = Aesthetic Sensitivity, CC = Contextual Cueing; *Significant at $p < .01$.

Discussion

We did not support our hypotheses in the current study. SPS showed no association with CC effect, nor with global attention bias. Further, we found no association between CC effect and global attention bias, which replicated *Study One* and failed to support previous research (Bellaera et al., 2014).

We found no association between SPS and CC effect, therefore high SPS individuals did not show greater statistical learning, as we expected. This suggests that high SPS individuals are not better at picking up subtle statistical regularities in the environment. However, we failed to find the basic CC effect in our task, as we found no interaction between trial type and epoch, as participants became faster to respond to both old and new trials at a similar rate throughout the task. This was unfortunate, as the CC effect has been shown to be a robust phenomenon in the literature and we based our task exactly on a previous paradigm (Bellaera et al., 2014). Future research should conduct extensive piloting in order to make sure the CC effect is robust in the particular sample of interest.

We also found no association between SPS and GL attention bias index, as high SPS individuals were not more locally biased, as we expected. This replicates the null result found in *Study One* and suggests that high SPS individuals do not have more of a narrow focus of attention. The GL task appeared to work as expected, as overall global trials were responded to the fastest, therefore we can be more confident in these results, compared to the CC task, which did not perform as expected.

Finally, we were once again unable to replicate the association between GL attention bias and CC (Bellaera et al., 2014), which again may have been due to our failure to find the basic CC effect. However, this calls into question the validity of the previously reported finding and highlights the need for this effect to be replicated.

General Discussion

The aim of the current study was to investigate potential cognitive mechanisms which might underlie environmental sensitivity. We predicted that high SPS individuals would show increased statistical learning, on an implicit CC task. However, across two studies we failed to find any evidence to support this hypothesis. We further predicted that high SPS individuals would show more of a local attention bias, which has been shown to predict greater levels of statistical learning (on the CC task). We did not support any of these hypotheses, as we found no association between SPS and local attention bias, nor between local attention bias and CC effect, across two experimental studies.

The CC task was designed to measure implicit statistical learning, as old trials, which are repeatedly presented throughout the task, are responded to faster than new trials, which are random configurations of stimuli, which is known as the CC effect and is expected to occur halfway through the task. A crucial interaction is predicted between trial type and epoch, as old trials start to become responded to significantly faster than new trials, in the

second half of the task. In the current study we observed this interaction in *Study One*, although there was an error in the task, as the orientation of distractors in old trials was fixed to one orientation as opposed to four, making these trials easier to perform from the very start. In *Study Two*, we failed to observe this interaction, suggesting that no CC effect occurred. This was also evident by the large variability in CC effect scores, as many participants responded faster to new trials, giving a negative CC effect score, which is not expected and suggests that the task was not a reliable or valid measure of statistical learning. Given this, it is not possible to draw any firm conclusions on whether SPS is related to statistical learning from the current study.

We expected that high SPS individuals would show greater statistical learning, because it is predicted that they are particularly sensitive to noticing subtleties in the environment and engaging deeper cognitive processing strategies (Aron et al., 2012). We chose to use a visual learning task, as previous research found that high SPS individuals performed better on a standard visual search task (Gerstenberg, 2012), and were better at noticing subtle changes on a change detection task (Jagiellowicz et al., 2011). This was the first study to test SPS in relation to an implicit learning task, therefore was somewhat exploratory, however theories of environmental sensitivity predict that highly sensitive individuals show greater responsivity to the environment due to a general learning mechanism, therefore the CC task seemed ideal to capture this. Future research should consider conducting extensive piloting of the CC task, as designing a task based on the specifications of previous research was not adequate for creating a reliable and valid task in the current study.

The GL task was designed to assess individual differences in GL visual processing. We expected high SPS individuals to show more of a local attention bias, which has been shown in various populations, such as those exhibiting autistic traits (Koldewyn et al., 2013)

and low mood (Basso et al., 1996; Tyler & Tucker, 1982). The affect-as-information model proposes that positive mood widens attentional breadth and negative mood narrows attentional breadth (Martin et al., 1993; Schwarz & Clore, 1983). We found no evidence to support this model, as high SPS participants, who exhibited lower mood, did not show more of a local attention bias. However, we assessed GL bias with a RT task, while previous research has often used assessments of preferential processing, whereby participants are asked to choose between two competing stimuli at the global and local level (Basso et al., 1996). Future research might consider using more traditional tasks of preferential GL processing in relation to SPS, rather than the RT task used in the current study.

We assessed GL processing by means of a RT task, in order to replicate previous research, which found that local attention bias predicted greater statistical learning, using the same tasks in the current study (Bellaera et al., 2014). This study concluded that local attention bias aids the CC effect by narrowing attention on the area surrounding the target, which may increase implicit statistical learning and decrease response times. We found no evidence to support this, however we also failed to find the basic CC effect, which could have explained this result. Again, future research should consider extensive piloting of the CC task to check that the basic effect can be found.

This study should be considered in light of its limitations. Firstly, the failure to find the necessary CC effect, meant that we were unable to provide an adequate and reliable measure of statistical learning. Further limitations include the sample, as all participants were university students, thus representing a homogeneous group, which may not be ideal for assessing individual differences. Using a more heterogeneous community sample could have been better, as the student sample may have displayed fairly similar levels of cognitive ability and learning. Further, we used extreme-groups sampling in *Study One*, which may have been better for assessing subtle individual differences, as compared to *Study Two*, which used

simple random sampling. This was evident in the fact that we did observe a group difference in error rates on the CC task in *Study One*, but not in *Study Two*, as the high SPS group committed fewer errors, which was in line with previous research (Gerstenberg, 2012).

Understanding cognitive mechanisms which support increased learning from the environment may provide insight into individual differences in environmental sensitivity. Future research should consider assessing SPS in relation to other tasks that require processing of environmental subtleties. We based our assumption that high SPS individuals would show greater statistical learning on theories of general environmental sensitivity, such as differential susceptibility. However, it is unclear whether high SPS individuals are more sensitive to the environment in a general way, as we previously found that they showed heightened responsivity to negative experiences, but attenuated responsivity to positive experiences (*Chapter 2 & 3*). Given this, other cognitive mechanisms, associated with increased sensitivity to negative stimuli, may provide a better example of a mechanism associated with high SPS. For example, sensitivity to punishment may be characteristic of high SPS individuals. This could be assessed cognitively with tasks that assess behavioural responses to reward and punishment. Based on the differential susceptibility hypothesis, one might predict that high SPS individuals would be highly sensitive to both reward and punishment. However, based on the assumption that high SPS is simply a risk factor, one might predict that high SPS individuals would only show heightened responsivity to punishment.

In conclusion, the current study predicted that high SPS individuals would show increased statistical learning from the environment in a general way, on a standard CC task, which could also be related to greater local visual processing. However, we failed to support any of our hypotheses, as no group differences were observed on the cognitive tasks measured. The results from the CC task cannot be interpreted appropriately, as we failed to

find the basic CC effect in our task. We can be more confident in the GL task results, therefore high SPS individuals do not appear to show more of a local attention bias, as initially predicted. Future studies should consider extensive piloting if using the CC task, or should investigate other cognitive tasks, which might support increased environmental sensitivity, such as tasks that assess individual differences in responsivity to reward and punishment.

Chapter 6

6

Is Sensory- Processing Sensitivity associated with differences in Reinforcement Learning?

Abstract: Sensory-Processing Sensitivity (SPS) describes a trait reflecting heightened environmental sensitivity, which is supported by studies of environmental moderation, using self-report measures. However, cognitive mechanisms which might support this increased environmental sensitivity are largely unknown. The current study tested the association between SPS and a reinforcement learning task designed to measure sensitivity to reward and punishment. It was hypothesised that high SPS individuals would show increased learning from both reward and punishment, due to a general mechanism reflecting heightened environmental sensitivity. In a large random sample of adults ($N = 397$), no group differences in reward or punishment learning were observed, across high SPS ($n = 119$), low SPS ($n = 97$), or average SPS ($n = 166$) groups, failing to support the hypotheses. This may have been related to the particular task used, which might have not been sensitive enough to pick up reliable individual differences in a healthy sample. Future research should consider using neural recordings, such as by electroencephalogram (EEG), which can be regarded as more direct measurements of cognition, compared to behavioural indices alone.

Introduction

Sensory-Processing Sensitivity (SPS) describes a personality trait reflecting variability in *Environmental Sensitivity*, which is defined as the ability to process and respond to the external environment (Pluess, 2015a). SPS, as measured with the *Highly Sensitive Person Scale* (HSPS: Aron & Aron, 1997), is normally distributed in the population and can be considered a continuous trait, although recent research purports that there may be three latent groups within this continuum (Lionetti et al., 2018). The high SPS group (reflected by the top 30% of scorers on the HSPS) are expected to be the most environmentally sensitive. Traditionally, this group has been described as highly emotionally reactive, sensitive to environmental subtleties, prone to cautious behaviour in novel situations and thought to engage deeper cognitive processing strategies (Aron & Aron, 1997; Aron et al., 2012). Research suggests that high SPS individuals are indeed more sensitive to the environment, as they tend to show heightened responsivity to different contextual conditions. For example, relative to low SPS individuals, they display increased levels of psychopathology in combination with environmental adversity, supporting diathesis-stress (Aron & Aron, 1997; Booth et al., 2015; Liss et al., 2005). More recently they have also been shown to display heightened responsivity to positive contextual conditions, including a treatment intervention (Pluess & Boniwell, 2015) and a positive mood induction (Lionetti et al., 2018), supporting differential susceptibility. However, while high SPS appears to be a trait reflecting heightened environmental sensitivity, little is known about underlying cognitive mechanisms which might support this enhanced sensitivity.

Learning from reward and punishment is a rudimentary mechanism, which might underlie variation in environmental sensitivity. This ability, known as reinforcement learning, is crucial for development and been described as a “prerequisite for flexible behavioural adaptation to changing environmental conditions” (Unger, Heintz, Kray, 2012,

p.1).. Reinforcement learning is thought to be modulated by the mesencephalic dopamine system in the brain, as better than expected outcomes produce positive dopamine signals, while worse than expected outcomes produce negative dopamine signals, therefore behaviour associated with punishment is less likely to be performed and behaviour associated with reward is more likely to be performed, due to this dopaminergic reinforcement (Holroyd & Coles, 2002). Individuals have been shown to vary in their degree of responsivity to reward and punishment (Carver & White, 1994), which could reflect a mechanism of environmental sensitivity. Hypersensitivity to punishment may reflect a mechanism underlying diathesis-stress, due to added saliency associated with negative reinforcement. This is supported by studies showing that hypersensitivity to punishment is related to increased fear and anxiety, while hypersensitivity to reward is related to increased impulsivity and risk-taking behaviour (Chiu & Deldin, 2007; Kambouropoulos & Staiger, 2001; Moser, Moran, Schroder, Donnellan, & Yeung, 2013). Although it is possible that hypersensitivity to reward and punishment may reflect a vantage factor, which increases learning from the environment in a general way, supporting a model of differential susceptibility. High SPS is thought to reflect heightened environmental sensitivity, within a differential susceptibility framework, therefore heightened reinforcement learning may be an intermediary cognitive mechanism.

Gray's revised *Reinforcement Sensitivity Theory* (RST) (Gray & McNaughton, 2003) describes three interacting neural systems, which underlie reinforcement learning. The fight-flight-freeze system (FFFS), which is sensitive to all forms of aversive stimuli and mediates fear behaviour. The behavioural activation system (BAS), which is sensitive to all forms of appetitive stimuli and mediates 'anticipatory pleasure' behaviours, related to impulsivity and reward seeking. Finally, the behavioural inhibition system (BIS), which is responsible for the resolution of goal conflict between the approach-motivated BAS and the avoidance-motivated FFFS (Pickering & Corr, 2008). Although not directly related to the revised RST,

Carver and White's (1994) BIS/BAS self-report scales have been widely used to assess trait individual differences in reward and punishment sensitivity (Carver & White, 1994). High trait BIS has been shown to strongly correlate with neuroticism and negative affect, while high trait BAS subscales (i.e., Reward Responsiveness, Drive and Fun-Seeking) have been shown to correlate strongly with extraversion and positive affect (Heubeck, Wilkinson, & Cologon, 1998). High SPS has been shown to strongly correlate with high BIS and moderately with high Reward Responsiveness (BAS-RR) (Pluess et al., 2018; Smolewska et al., 2006). This suggests that high SPS individuals are highly motivated by reward, but also display high levels of BIS, resulting in increased goal conflict, which could explain inhibited behaviour in response to fear or novelty, which is characteristic of high SPS. Research is yet to be conducted looking at the association between SPS and reinforcement learning on a behavioural level, although previous research has investigated reinforcement learning with regard to the BIS/BAS scales, which was used as a proxy to develop our hypotheses for the current study.

Neurocognitive studies of Event-Related Potentials (ERPs) have revealed some interesting findings with regard to reinforcement learning and trait differences in BIS/BAS. The feedback related negativity (FRN) is a negative deflection observed over the medial prefrontal cortex (mPFC), which peaks around 250ms after task feedback is given. It has been shown to be more sensitive to negative feedback than positive feedback and to be related to higher trait BIS (De Pascalis, Varriale, & D'Antuono, 2010; Unger et al., 2012). Further, an interaction between BIS/BAS has been observed, as individuals high in both BIS and BAS-RR displayed the largest FRN amplitude in response to negative feedback in the form of punishment cues (De Pascalis et al., 2010). Given that high SPS individuals are likely to be high in both BIS and BAS-RR, we expect that they will be particularly sensitive to punishment and therefore learn better from punishment. In another study, assessing multiple

ERP components, it was found that high BIS was related to worse task performance on a probabilistic learning task, which may have been explained by heightened error-monitoring, reflected by larger FRN amplitudes and resulting in increased task anxiety (Unger et al., 2012). The same study revealed better task performance in relation to high BAS, which was mediated by enhanced error related negativity (ERN) and error related positivity (PE) amplitudes. It is possible that high SPS individuals display general heightened neuro-sensitivity, which may result in better learning from instances of both reward and punishment.

In the current study, we measured reinforcement learning with the Passive Avoidance Task (PAT). In this task, participants are instructed to learn which stimuli are ‘good’ and result in points gained, so that they always respond to these. They also simultaneously learn which stimuli are ‘bad’ and result in points lost, so that they always withhold responding to these (i.e. passive avoidance). Across ten blocks, ten different stimuli (five ‘good’, five ‘bad’) are repeatedly presented. Participants receive feedback after making a response as to whether points were gained or lost. Errors made on punishment trials are known as ‘passive avoidance errors’, as they reflect the commission of an erroneous response. Errors made on reward trials reflect ‘omission errors’, as they reflect a failure to respond to a rewarding stimulus. Over time, accuracy levels should increase, as participants learn from reward and punishment cues. The task is difficult, as it requires holding ten stimuli in working memory, as well as involving the need to change cognitive set between ‘good’ (rewarding) and ‘bad’ (punishing) stimuli, in a speeded environment. This can result in a trade-off between learning better from reward or punishment cues, which is valuable for assessing individual differences.

Although to our knowledge the PAT has never been tested in relation to SPS, evidence from other populations supports our predictions. For instance, it has been observed

that introverts commit fewer passive avoidance errors compared to extraverts, which may reflect greater punishment sensitivity (Newman, Widom, & Nathan, 1985). Although correlations are small, high SPS is related to introversion (Aron & Aron, 1997; Pluess et al., 2018). Introverts have also been shown to pause after committing erroneous punished responses, while extraverts tend to speed up, which may reflect a greater tendency to reflect and learn from punishment across introverted individuals (Nichols & Newman, 1986). Further studies have supported the role of individual differences in behavioural inhibition and performance on the PAT. For example, it has been shown that psychopathic individuals, who are characterised by behavioural disinhibition, display reduced learning from punishment, reflected by increased passive avoidance errors on the PAT (Blair et al., 2004; Newman, Patterson, Howland, & Nichols, 1990; Newman & Schmitt, 1998; Newman et al., 1985; Patterson & Newman, 1993). Interestingly, a study with the PAT comparing task performance in individuals grouped by the serotonin transporter polymorphism (Finger et al., 2007) found that *s* allele carriers made fewer passive avoidance errors than *l* allele carriers. This is relevant to SPS, as the *s* allele is thought to increase responsivity to negative environments, in a similar way as high SPS (Homberg, Schubert, Asan, & Aron, 2016). Thus, high SPS and the *s* allele may both provide examples of individual factors related to heightened punishment sensitivity.

The aim of the current study was to investigate SPS in relation to a cognitive task that requires learning simultaneously from reward and punishment. Given previous research, we hypothesised that high SPS individuals would be particularly sensitive to punishment, as they are particularly sensitive to negative life experiences (Aron & Aron, 1997; Booth et al., 2015; Liss et al., 2005), and they are likely to display high levels of BIS (Pluess et al., 2018; Smolewska et al., 2006), which is related to heightened neuro-sensitivity to punishment (De Pascalis et al., 2010). We had less reason to expect an association between SPS and sensitivity

to reward, although we hypothesised that high SPS individuals may also display greater reward sensitivity, as they have previously been shown to benefit more from positive contextual conditions (Lionetti et al., 2018; Pluess & Boniwell, 2015), and they are likely to display high levels of BAS-RR (Pluess et al., 2018; Smolewska et al., 2006). As the study was exploratory, we could not conduct a power analysis to determine the sample size, therefore we aimed to test a large sample (c. 400 participants) to reduce the likelihood of Type II error. Previous research comparing different groups used much smaller samples of 35 (Finger et al., 2007) and 90 individuals (Newman et al., 1985).

Recent latent class analyses suggest that there are three distinguishable SPS groups – a high SPS group reflected by the top 30%, a low SPS group reflected by the bottom 30%, and an average SPS group reflected by the middle group of scorers (Lionetti et al., 2018). Thus, we split our sample according to this, in order to test our hypotheses. We didn't have any specific hypotheses on task performance according to low and average levels of SPS, as research is yet to be conducted on such specific groupings, although we expect a linear increase in sensitivity with increasing SPS. We controlled for levels of visuospatial working memory and depression in our analyses, which could have affected performance on the PAT. We also assessed the factorial structure of SPS, according to previous research supporting a three-factor structure (Pluess et al., 2011; Smolewska et al., 2006), in order to run exploratory analyses on the association between task performance and the different components of SPS.

Hypotheses

- 1) We predicted that the high SPS group would display heightened learning from punishment (indicated by fewer passive avoidance errors on the PAT), in comparison to the low SPS group and the average SPS group.

- 2) We predicted that the high SPS group would display heightened learning from reward (indicated by fewer omission errors on the PAT), in comparison to the low SPS group and the average SPS group, although this hypothesis was more tentative.

Method

Participants

In total 397 individuals took part in the experiment, although only 374 completed all of the tasks and questionnaires due to various technical reasons. Participants were all recruited from an online database called *Prolific Academic*. They were reimbursed £3.50 for taking part in the experiment, which involved completing a survey, which was used for *Chapter 3*, as well as completing two cognitive tasks for the current study. The sample was aged between 18 and 55 (*mean age = 34.38, SD = 3.37*) – 60% female.

Measures

Questionnaires

Demographics. Participants indicated their gender (i.e., male, female, other), their age in years (free text box), and their highest level of completed education (1 = “Secondary school”, 2 = “Vocational/technical school”, 3 = “Some college”, 4 = “Bachelor’s degree”, 5 = “Master’s degree”, 6 = “Doctoral degree”).

The Highly Sensitive Person Scale – Short Form (HSPS-SF) (Pluess et al., 2011). The 12-items were mean score averaged. Overall the scale showed good internal consistency (Cronbach’s $\alpha = .81$). Results from the PCA were reported in *Chapter 3 – Appendix A* (p. 100). It found a three-factor solution explaining 61% of total variance. The item loadings

matched previous factor analyses, resulting in the factors: Ease of Excitation (EOE), Low Sensory Threshold (LST) and Aesthetic Sensitivity (AES).

The Patient Health Questionnaire (PHQ-9) (Spitzer et al., 1999). The 9-items were summed to generate a depression severity score. The scale showed excellent internal consistency (Cronbach's $\alpha = .90$). Scores ≥ 5 reflect mild depression, scores ≥ 10 reflect moderate depression, scores ≥ 15 reflect moderately severe depression, and scores ≥ 20 reflect severe depression.

Cognitive tasks

The Passive Avoidance Task (PAT) (Blair et al., 2004; Finger et al., 2007). The PAT was a variation of earlier used versions of this task. We used shape stimuli instead of numbers. The task consisted of ten blocks, and in each block, participants were shown ten unique shapes in a random order. They were instructed to learn which shapes were 'bad' and resulted in points lost and to which they should always withhold their response. They were also instructed to learn which shapes were 'good' and resulted in points gained and to which they should always make a response. Responses were made by pressing the left mouse button. Half of the shapes were 'bad' and half were 'good'. A points total was always visible at the bottom of the screen, which started at 0. The sets were created such that they included equal numbers of round vs. sharp shapes and common vs. uncommon shapes within each set (Appendix A – p. 200). The 'bad' and 'good' sets were counterbalanced across participants. Shapes were assigned to a graded reinforcement schedule, as for bad shapes: S-1 resulted in a loss of 400 points, S-2 resulted in a loss of 800 points, S-3 resulted in a loss of 1200 points, S-4 resulted in a loss of 1600 points and S-5 resulted in a loss of 2000 points. Similarly for good shapes, S+1 resulted in a gain of 400 points, S+2 resulted in a gain of 800 points, S+3 resulted in a gain of 1200 points, S+4 resulted in a gain of 1600 points and S+5 resulted in a

gain of 2000 points. Shapes were blue presented on a black background. Feedback in the form of a “+” or “~” and the number of points was shown directly below the shape immediately after a response was made. The points total was also updated immediately after a response. Each trial lasted 3 seconds. There was an inter-trial interval of 500ms. Based on previous research, we excluded the first block from analysis, as this was the first instance that feedback was shown (i.e. before learning could occur). For the following 9 blocks, a total of passive avoidance errors was computed as the number of times a participant responded to a ‘bad’ shape, as well as a total for omission errors, which was the number of times a participant failed to respond to a ‘good’ shape.

The Corsi Block-Tapping Task (CBTT) (Corsi & Michael, 1972; Kessels, Van Zandvoort, Postma, Kappelle, & De Haan, 2000). The CBTT was used to measure visuospatial working memory. Participants were shown 9 squares fixed on the screen in a pseudorandom position (Appendix B – p. 200). The squares ‘lit up’ in different sequences and the participant was instructed to recall the sequence by clicking on the squares in the order they lit up. The squares were blue and approximately 3cm isotropic, presented on a black background. The squares ‘lit up’ by changing to yellow for 1 second during the encoding phase. After encoding, participants were instructed to click on the squares in the correct sequence order and then press the button labelled ‘Done’ when they were finished, or press the button labelled ‘Reset’ to start the recall phase again. Clicking on a square during the recall phase also made the blue square change to yellow. The sequence length started at two and increased by one every time two sequences were recalled correctly. The task ended when participants recalled twice incorrectly. The maximum sequence length was 9. As standard, a score was computed by multiplying the highest achieved block span with the number of correctly recalled sequences. The highest possible score was 144. We used the CBTT as a control variable for any possible effects of memory on the PAT.

Procedure

Participants completed the questionnaires in the order reported above followed by the PAT and the CBTT. *Inquisit* software was used and all measures were delivered online.

Statistics

Descriptive statistics and bivariate correlations were first explored on the total sample means. We then created three SPS groups using information from previous latent class analyses, suggesting that the HSPS-SF is able to differentiate between a low group (lowest 30% of scores), an average group (middle 40% of scores) and a high group (top 30% of scorers) (Lionetti et al., 2018). The suggested cut-off scores from this previous research were for > 3.71 to represent average scores and for > 4.66 to represent high scores. We split our sample by attempting to match the distributions from the previous research (i.e., 30% in both the high and low group), rather than relying on the suggested cut-off scores. Our cut-off scores were higher than previously seen as > 3.99 represented average scores and > 5.00 represented high scores, which resulted in a low group ($n = 97$), an average group ($n = 166$) and a high group ($n = 119$). We then ran two separate 9 (block) x 3 (SPS group) repeated measures ANOVAs for passive avoidance and omission errors separately, controlling for working memory capacity (CBTT performance). Analyses were run with and without participants reporting severe levels of depression ($n = 25$), although this did not change the results, therefore analyses are reported on the total sample.

Results

Preliminary Analyses

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Table 1 shows descriptive statistics and bivariate correlations for all of the relevant variables. The average number of Passive Avoidance (PA) errors were not significantly different from the average number of Omission (O) errors on the PAT, $t(385) = -1.61, p = .109, d = .12$. We found a moderate positive correlation between SPS and depression, as high SPS was related to higher rates of depression. The factor EOE showed the largest correlation with depression. There was no significant correlation between SPS and performance on the PAT, as SPS was unrelated to the total number of PA or O errors. There was a small negative correlation between SPS and the CBTT, indicating that higher SPS was related to slightly lower levels of working memory capacity. Although, LST was the only SPS factor that showed this correlation. PA errors and O errors from the PAT were uncorrelated. The CBTT showed a small negative correlation with PA errors and a small to moderate negative correlation with O errors, suggesting that poor performance on the PAT was related to lower working memory capacity, particularly in the reward condition.

Table 1. *Descriptive statistics and bivariate correlations between variables (N = 397)*

Variable	<i>N</i>	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1 SPS	389	4.48	.94	-						
2 EOE	389	4.80	1.31	.83*	-					
3 LST	389	3.59	1.50	.80*	.50*	-				
4 AES	389	4.80	1.10	.57*	.14*	.30*	-			
5 Depression	389	8.40	6.34	.34*	.40*	.21*	.10	-		
6 PA errors	385	12.66	7.46	-.04	-.02	-.04	-.10	-.02	-	
7 O errors	385	11.60	9.92	-.03	-.04	.10	-.10	.03	-.10	-
8 CBTT total	382	53.92	23.91	-.14*	-.10	-.21*	-.04	-.10	-.14*	-.28*

Note: SPS = Sensory Processing Sensitivity; EOE = Ease of Excitation; LST = Low Sensory Threshold; AES = Aesthetic Sensitivity; PA errors = Passive Avoidance errors; O errors = Omission errors; CBTT = Corsi Block Tapping Task (working memory capacity); *Correlation is significant at $p < .01$ level (2-tailed).

Passive Avoidance (PA) Errors

Group differences on PA errors were examined using a 3 (SPS group) x 9 (block) repeated measures ANOVA including CBTT performance as a covariate. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of block, $X^2(35) = 468.04, p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = .75$). There was a significant main effect of block, $F(5.97, 2255.21) = 40.89, p < .001, \eta^2 = .10$. Contrasts revealed that this was a linear trend, $F(1, 378) = 138.14, p < .001, \eta^2 = .27$, indicating that PA errors decreased with each block. There was no interaction between block and SPS group, $F(11.93, 2255.21) = 1.09, p = .356, \eta^2 = .01$, indicating that the groups did not differ in PA errors across the blocks. There was no interaction between block and CBTT performance, $F(5.97, 2255.21) = 1.02, p = .412, \eta^2 = .00$, indicating that differences in working memory did not affect PA errors across the blocks. Tests of between-subjects effects revealed that there was no main effect of SPS, $F(2, 378) = 1.35, p = .259, \eta^2 = .00$, indicating that there was no main effect of SPS on PA errors overall. These null findings are shown in **Figure 1**. There was a main effect of CBTT performance, $F(1, 378) = 10.86, p < .001, \eta^2 = .03$, which was investigated further with partial correlations, controlling for SPS. This revealed that greater PA errors were related to lower working memory capacity, $r = -.14, p = .005$.

Omission (O) Errors

Group differences on O errors were assessed using a 3 (SPS group) x 9 (block) repeated measures ANOVA including CBTT performance as a covariate. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of block, $X^2(35) = 837.67, p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = .61$). There was no main effect of block, $F(4.87, 1839.14) = 1.61,$

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$p = .157$, $\eta^2 = .00$, indicating that O errors did not decrease across blocks. There was no interaction between block and SPS group, $F(9.73, 1839.14) = .59$, $p = .821$, $\eta^2 = .00$, indicating that the groups did not differ in O errors across the blocks. There was a significant interaction between block and CBTT performance, $F(4.87, 1839.14) = 3.01$, $p = .011$, $\eta^2 = .01$. Tests of between-subjects effects revealed that there was no main effect of SPS, $F(2, 378) = 1.05$, $p = .352$, $\eta^2 = .01$, indicating that there was no main effect of SPS on O errors overall. These null findings are shown in **Figure 1**. There was a main effect of CBTT performance, $F(1, 378) = 33.00$, $p < .001$, $\eta^2 = .10$, which was followed up with partial correlations, controlling for SPS. This revealed that more O errors were related to lower working memory capacity, $r = -.29$, $p < .001$.

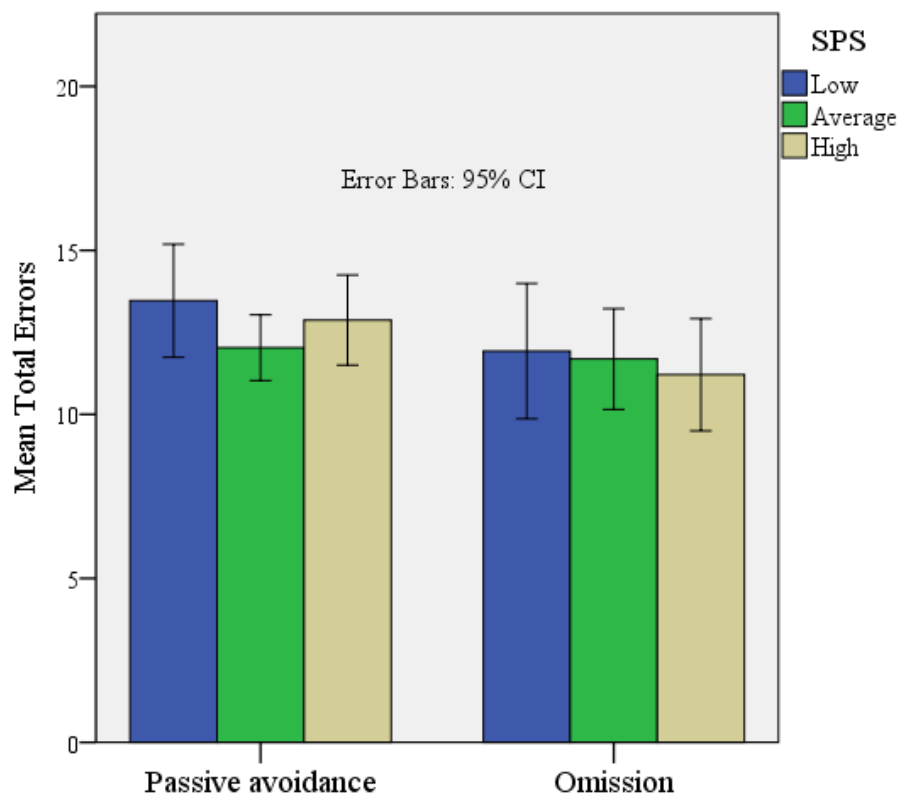


Figure 1. Mean total number of Passive avoidance and Omission errors by SPS group (low, average, high).

Discussion

The current study investigated the potential association between the trait SPS and performance on a reinforcement learning task. The results did not support our hypotheses, as SPS was not related to performance on the PAT. Specifically, high SPS individuals did not show greater learning from either punishment or reward, as predicted.

We found that high SPS was related to higher levels of depression, which supports previous research (Liss et al., 2008; Liss et al., 2005). Specifically, the factor EOE, which is related to becoming overwhelmed by increasing stimulation, showed the strongest association with depression, which replicated the results from *Chapter 5*. The factor LST also showed a modest positive correlation with depression, whereas AES was uncorrelated with depression. This is consistent with previous research, which suggests that EOE and LST are associated with negative affect, while AES is more likely to be associated with positive affect (Lionetti et al., 2018; Pluess et al., 2018; Sobocko & Zelenski, 2015), suggesting that SPS is a multifaceted concept and that the different components are related to different affective outcomes.

We found a small negative correlation between SPS and performance on the CBTT, which suggests that high SPS individuals have slightly lower working memory capacity. The only factor that supported this association was LST, which describes unpleasant arousal in response to strong sensory input. Previous research found that LST was the only factor explaining the association between high SPS and better performance (faster response times and fewer errors) on a standard visual search task (Gerstenberg, 2012). This suggests that high SPS individuals are more sensitive to sensory input, which may be beneficial in certain tasks, such as simple visual processing, while being detrimental in tasks that put constraints on working memory. This may be related to increased levels of anxiety, as *Attentional*

Control Theory predicts that high trait anxious individuals display lower working memory capacity, due to interference from the stimulus-driven attentional system, which disrupts top-down cognitive control (Derakshan & Eysenck, 2009; M. W. Eysenck, Derakshan, Santos, & Calvo, 2007). While LST (and SPS in general) have previously shown moderate positive correlations with anxiety (Liss et al., 2008), future research should attempt to replicate the association between SPS and working memory, to support this theory.

Increased passive avoidance and omission errors from the PAT were related to lower working memory capacity on the CBTT. This suggests that working memory was supportive of performance on the PAT in both the reward and punishment conditions, although the effect was larger in the case of reward trials. This could be explained as the reward trials were slightly easier to learn than the punishment trials, which was evident from near ceiling performance on reward trials from the beginning of the task. Therefore, poor performance on these trials could be indicative of significant impairments in working memory. These associations support our decision to include working memory as a covariate in our later models.

We found that the two error conditions from the PAT were uncorrelated, suggesting that they are measuring different constructs. While omission errors may reflect impairments in (active) reward seeking, passive avoidance errors may reflect impairments in (passive) punishment avoidance, which may be unrelated. If a trade-off had occurred between learning better from either reward or punishment, then we may have expected to find a negative correlation. Alternatively, if the two indices measure similar constructs, then we may have expected to find a positive correlation. Although previous research did not report on such correlations, therefore cannot support our suggestions (Blair et al., 2004; Finger et al., 2007).

Future research could investigate the association between passive avoidance and omission errors further.

We did not support our main hypothesis, that high SPS individuals would be more sensitive to punishment, reflected by fewer passive avoidance errors. This was not likely due to low power, as we had fairly large groups and the effect size for SPS on passive avoidance errors was insignificant ($\eta^2 = .00$). This was in contrast to the main effect of block on passive avoidance errors, which showed a small effect ($\eta^2 = .10$), yet perfect observed power (1.00), computed at the .05 level of significance. This suggests that SPS is unrelated to punishment learning assessed with the PAT. However, this does not mean that SPS is unrelated to reinforcement learning using different tasks or measures, which could be investigated in future research. For example, it has been shown that individuals at risk for depression display greater attentional biases for punishment conditioned shapes, while those not at risk display attentional biases for reward conditioned shapes (Brailean, Koster, Hoorelbeke, & De Raedt, 2014).

The PAT may not be sensitive enough to pick up any individual differences in a healthy sample. According to seminal research, the average person can hold seven items (plus or minus two) in their short-term memory (Miller, 1956). Therefore, we expected that ten items would be sufficiently difficult to assess variability in performance. However, due to the nature of the task, participants would have been able to segment stimuli into two groups of five stimuli (e.g., ‘good’ vs. ‘bad’ shapes), a phenomenon known as ‘chunking’, which can increase the capabilities of short-term memory. Previous research with the PAT has used either eight (Blair et al., 2004; Newman et al., 1990; Newman et al., 1985) or twelve stimuli (Finger et al., 2007), thus the choice of ten stimuli would appear to be a happy medium. However, the studies which used eight stimuli were often conducted in abnormal populations,

such as within prison institutions (Blair et al., 2004), thus the task may not demonstrate the same pattern of results for normal populations. We were concerned about making the task too difficult, as it was delivered online, outside the support of a trained researcher. However, the participants were not naïve to testing, as they were all members of an online community taking part in research studies, and the majority reported a high level of education. Based on these reasons, future research might consider using more stimuli on the PAT when testing normal healthy samples, in order to increase measurement variability.

Evaluating the two conditions in more detail, using separate repeated measures ANOVAs, we found that passive avoidance errors decreased with each block, while omission errors remained at a constant low level throughout the task, which replicated previous research (Blair et al., 2004; Finger et al., 2007). This suggests that learning occurred in the punishment condition, but not in the reward condition, as performance was almost at ceiling for reward trials from the beginning of the task. However, this is likely an artefact of the task design, as the task encourages pre-potent responding in order to receive feedback. Further, responding is considered a correct response in reward trials, therefore some correct responses in reward trials are likely to be false positives. This suggests that the task may not be ideal for assessing variability in reward learning, which can be explained as the task was originally designed to assess variability in punishment learning associated with passive avoidance (Newman et al., 1985). Future research might consider changing the conditions, so that reward is linked with passive avoidance and avoiding punishment is linked with response commission, in order to see whether results hold relative to the active vs. passive nature of the task.

Future research might consider the use of brain activity recording in relation to SPS. High SPS individuals are expected to show heightened neural sensitivity, which supports

greater environmental sensitivity (Aron et al., 2012). Therefore, studies which assess neural activity may be better placed to investigate cognitive mechanisms than behavioural measures alone. While previous fMRI studies have supported the notion of increased neural sensitivity in high SPS individuals (Acevedo et al., 2014; Jagiellowicz et al., 2011), to our knowledge no EEG studies have been conducted. *Attentional Control Theory* posits that high trait anxious individuals use compensatory mechanisms to support cognition, therefore cognitive deficits associated with anxiety are often only visible in neural recordings, as opposed to behavioural measures (Derakshan & Eysenck, 2009; M. W. Eysenck et al., 2007). This suggests that neural measures may be better to investigate the cognitive underpinnings of SPS, as they directly assess the construct of interest, as opposed to behavioural indices, which can be considered indirect.

This study should be considered in light of its strengths and limitations. It tested a novel hypothesis, as reinforcement learning has never been tested in relation to SPS. Further, it assessed a relatively large sample, which is necessary for individual differences research. This was possible as we conducted the study online through *Prolific Academic*. However, the PAT may not have been sensitive enough to pick up any individual differences in this normal healthy sample. As discussed previously, future research might consider increasing the number of test stimuli or changing the response conditions. We also experienced some minor technical issues due to delivering the study online, as for various reasons not all participants completed the full test battery. Further, we could not control the effects of external distractions, as would have been possible if conducted in the lab.

In conclusion, high SPS individuals did not show heightened sensitivity to punishment or reward on the PAT, as expected. Future research in the neuro-cognitive

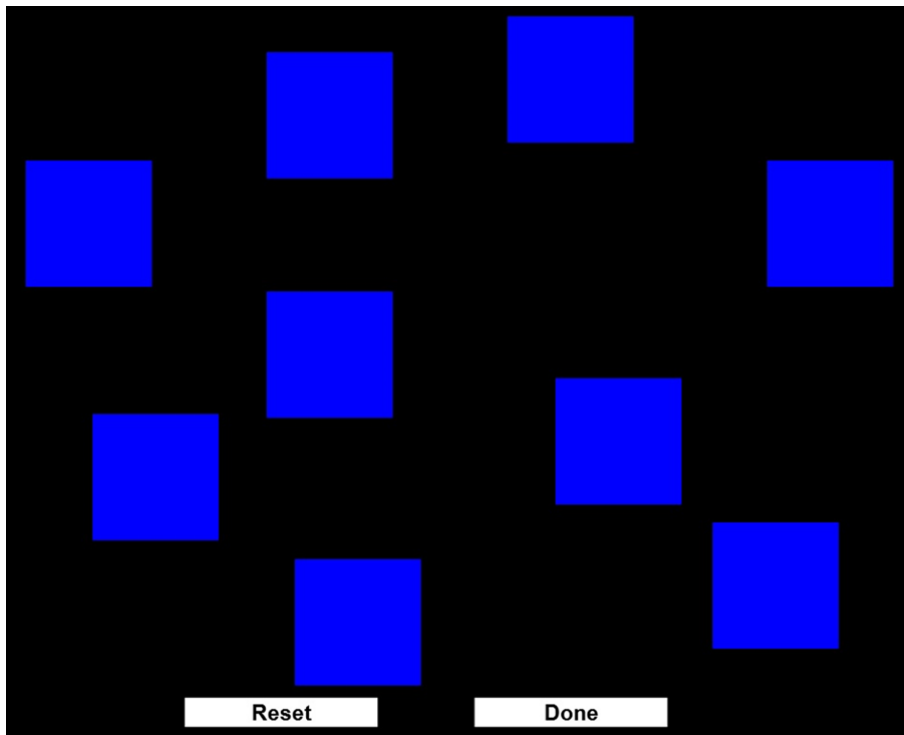
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domain could benefit from directly assessing neural measures of sensitivity, which may be more sensitive to pick up subtle cognitive differences associated with SPS.

Appendix A: Shapes from the Passive Avoidance Task (PAT), e.g., top row indicates ‘good’ set and bottom row indicates ‘bad’ set (counterbalanced)



Appendix B: Graphical representation of Corsi Block-Tapping Task (CBTT)



Chapter 7

7. Discussion

7

Discussion

Summary of Findings

The current thesis investigated whether the trait *Sensory-Processing Sensitivity* (SPS) reflects heightened environmental sensitivity and moderates the effect of environmental experiences on psychological outcomes (Part one: *Chapters 2, 3 & 4*). It also investigated whether SPS shows any associations with cognitive learning mechanisms, which could underscore mechanisms reflecting heightened environmental sensitivity (Part two: *Chapters 5 & 6*).

In *Chapter 2* we tested the moderation of SPS on positive and negative childhood experiences predicting wellbeing and job satisfaction in a cross-sectional study of adults ($N = 339$). We predicted that high SPS would reflect heightened environmental sensitivity, evidenced by a greater effect of childhood experiences on our outcome variables, relative to low levels of SPS. We found an interaction between SPS and negative childhood experiences predicting wellbeing, where high SPS individuals displayed the lowest levels of wellbeing in combination with increased levels of negative childhood experiences, as well as displaying the highest levels of wellbeing in combination with decreased levels of negative childhood experiences. This finding, consisting of a crossover interaction, supported a differential susceptibility model, as high SPS individuals displayed ‘for better and for worse’ outcomes. However, in our other model, we found that high SPS individuals displayed attenuated responsiveness to positive childhood experiences predicting lower wellbeing, as compared to

low SPS individuals. Low SPS individuals showed the expected effect of increasing levels of positive experiences predicting increasing levels of wellbeing, while high SPS individuals actually showed the opposite pattern of results, which was unexpected. Supplementary analyses revealed that this unusual finding, whereby increasing positive experiences predicted decreasing wellbeing at high SPS, was only apparent for the social wellbeing subscale. One potential interpretation of this finding is that high SPS individuals who experienced poor social functioning in childhood and adolescence spent more time with family members, reflected in a greater recall of positive family experiences, which was problematic for developing better social functioning. Future research should conduct longitudinal studies, as our study was cross-sectional and can therefore not infer the direction of results. .

Chapter 3 was an extension of the study reported in *Chapter 2*, as it tested the moderation of SPS on positive and negative childhood experiences predicting wellbeing and depression outcomes in a different sample of adults ($N = 389$). Yet in this study, we included emotion regulation as a mediator in the model, consistent with previous research suggesting that it is a key mechanism explaining the effect of negative childhood experiences on depression (Berking et al., 2014; Schierholz et al., 2016). Therefore, emotion regulation may represent a key intermediary mechanism between childhood experiences and affective outcomes, moderated by levels of environmental sensitivity. We predicted that emotion regulation would mediate the effect of childhood experiences on our outcomes, and that high SPS individuals would be more sensitive to the effects of childhood experiences predicting ‘for better and for worse’ outcomes (i.e. a moderated mediation model). We supported our mediation hypothesis, as emotion regulation fully mediated the effect of negative childhood experiences on wellbeing, as well as partially mediating the effect of negative childhood experiences on depression, supporting previous research. We also found that emotion

regulation partially mediated the effect of positive childhood experiences on both wellbeing and depression, which provides new evidence that the development of emotion regulation is partly dependent on positive early caregiver experiences. Unfortunately, we did not support our moderation hypothesis, as SPS did not moderate the effect of negative nor positive childhood experiences on any of our outcomes. This led us to conduct a combined analysis with the data reported in *Chapter 2* ($N = 727$), which did find moderation effects. High SPS individuals showed heightened responsivity to negative childhood experiences predicting lower wellbeing, consistent with diathesis-stress (i.e., no crossover interaction). High SPS individuals also showed attenuated responsivity to positive experiences, reflected by non-significant regression lines, while low SPS individuals showed the expected beneficial effect, suggesting that low SPS may represent a vantage factor with regard to positive childhood experiences. However, supplementary analyses revealed that the different SPS factors supported different models of environmental sensitivity. In the case of negative childhood experiences, high AES individuals showed for better and for worse levels of wellbeing, consistent with differential susceptibility. In the case of positive childhood experiences, high SPS individuals showed the expected beneficial effect on wellbeing, although the effect was reduced in comparison to low SPS individuals. Failure to find moderation with the smaller sample (i.e., in the moderated mediation model) could have been explained by low statistical power, as post-hoc power analyses conducted on the change in R^2 by adding the interaction term, revealed that in order to achieve power at the .80 level, a sample of 441 individuals was needed for the negative experiences interaction, and a sample of 646 was needed for the positive experiences interaction. Therefore, only the combined analysis had a good level of power. This underscores the need to test large samples to find interaction effects (see later *General Discussion*).

In *Chapter 4* we tested the moderation of SPS on positive and negative life events predicting wellbeing and depression, at two time-points, in the same sample of adolescents. At both Wave 1 ($N = 504$, $M_{age} = 13$, $SD = 0.8$) and Wave 2 ($N = 450$, $M_{age} = 14.5$, $SD = 0.6$) we found that SPS moderated the effect of negative life events predicting depression. High SPS adolescents displayed heightened responsivity to negative life events predicting greater levels of depression, consistent with a diathesis-stress model. These results replicated our previous findings and suggest that high SPS is a risk factor reflecting heightened responsivity to negative experiences in both adults and adolescents. We did not find any moderation of positive life events, nor moderation of life events on wellbeing, as we did in adults. This could have been related to low statistical power, or to the difference in measures. In this study, positive life events were assessed with a checklist of normative adolescent experiences rather than positive family experiences, and the measure of wellbeing may not have been valid for young adolescents.

In *Chapter 5*, we investigated whether SPS was related to statistical learning from the environment, which could provide a general learning mechanism underlying environmental sensitivity. We hypothesised that high (relative to low) SPS individuals would show greater statistical learning, indicated by a greater contextual cueing effect. We also hypothesised that high (relative to low) SPS individuals would show more of a local attention bias on a global-local task, due to greater contextual cueing, as well as general lower mood, in line with previous research (Basso et al., 1996; Bellaera et al., 2014). We did not support our hypotheses in a study using extreme groups sampling of high ($n = 29$) and low ($n = 28$) SPS individuals, nor in a correlational random samples study ($N = 79$). High SPS individuals did not show enhanced statistical learning on a contextual cueing task, nor an increased local attention bias on a global-local task. Problems with the reliability of the contextual cueing task could have explained these results, as we struggled to observe the basic learning effect.

Future research could benefit from investigating these associations further using different cognitive measures, such as tasks that do not rely on reaction-time indices, as well as testing larger samples.

Finally, in *Chapter 6* we investigated whether SPS was related to reinforcement learning, i.e., sensitivity to reward or punishment, using a passive avoidance task. We hypothesised that high (relative to low and average) SPS groups, would show enhanced learning from both reward and punishment, although we expected effects to be stronger in the punishment condition. Our hypotheses were not supported, as we observed no group differences on the passive avoidance task, in neither the punishment nor reward condition. This could have been related to the insensitivity of the particular task to pick up individual differences in a healthy sample, or could be related to a wider issue on the applicability of cognitive tasks for individual differences research (i.e., the *reliability paradox* – see later *General Discussion*).

General Discussion

Environmental Sensitivity

Sensory-Processing Sensitivity is a trait theorised to represent heightened environmental sensitivity, due to greater awareness and processing of environmental input (Aron et al., 2012). This has been supported in previous studies showing that high SPS individuals display greater responsivity to low parental care (Liss et al., 2005), and adverse childhood experiences (Booth et al., 2015), predicting poor wellbeing outcomes. Recently, it has also been found that high SPS individuals show better outcomes in response to positive experimental manipulations, including a school-based resiliency intervention (Pluess & Boniwell, 2015), a positive mood induction (Lionetti et al., 2018), and more recently in a

school-based anti-bullying intervention (Nocentini et al., 2018). Together, these findings support high SPS as a marker of heightened environmental sensitivity, yet it is unclear which model best represents this trait. Given that high SPS individuals have shown increased responsivity to both negative and positive experiences, it could be suggested that this trait reflects differential susceptibility. However, high SPS is consistently associated with poor mood outcomes, regardless of life experiences, which is problematic for inferring differential susceptibility, as such main effect associations often reflect diathesis-stress (Belsky & Pluess, 2009).

The current thesis sought to examine whether and how SPS moderates the effect of the environment, i.e. does it reflect differential susceptibility or simply diathesis-stress? Although a crossover interaction was observed in *Chapter 2* – as high SPS individuals appeared to show the best and worst wellbeing outcomes relative to the absence and presence of negative childhood experiences – (i) the effect was more pronounced in response to increasing negative experiences, (ii) higher SPS predicted lower wellbeing overall, and (iii) high SPS individuals showed attenuated responsivity to positive childhood experiences. Further, in *Chapter 3*, we discovered that we were likely underpowered to detect such interactive effects, therefore the results of *Chapter 2* were likely inflated estimates. The combined analysis with data collected in a new sample of adults, yielded a diathesis-stress interaction, as high SPS individuals showed the lowest levels of wellbeing, which decreased exponentially in response to negative childhood experiences. However, it is important to note that the AES components of SPS did show the ‘for better and for worse’ interaction with negative childhood experiences, therefore future research should consider whether the different factors of SPS support different models of environmental sensitivity. The interaction presented in *Chapter 4* supported diathesis-stress, as high SPS adolescents showed the highest levels of depression, which increased exponentially in response to

negative life events. Together, our studies suggest that high SPS, particularly the components EOE and LST, are risk factors for low wellbeing and high levels of depression, which can in some part be explained by heightened sensitivity to negative experiences.

We found no evidence that high SPS is a vantage factor, increasing responsivity to positive experiences. In fact, we found some evidence that high SPS individuals show attenuated responsivity to positive experiences, as increasing positive childhood experiences did not predict increasing wellbeing, as expected, and as was observed in low SPS individuals (*Chapter 2 & 3*). However, this attenuated interactive effect was smaller than the effect of responsivity to negative childhood experiences and was not observed in our adolescent sample (*Chapter 4*), therefore caution should be taken with the interpretation of this finding. Further, our measure of childhood experiences was retrospective and our study was cross-sectional, which limits our ability to conclude on the direction of effects. In sum, high SPS reflected heightened sensitivity to negative experiences, which was mostly consistent with a diathesis-stress model.

The theory of *Sensory-Processing Sensitivity* was developed with the aim to provide an empirical understanding of high sensitivity (Aron & Aron, 1997). Since then, little attempt has been made to interpret the meaning of low SPS. It has been suggested that low SPS individuals may be resilient to the negative effects of adverse experiences, but also benefit little from positive experiences (i.e., showing vantage resistance) (Pluess et al., 2018). However, we found that low SPS individuals showed heightened responsivity to positive childhood experiences predicting increased wellbeing, supporting vantage sensitivity. This was unexpected based on previous research, for example the intervention studies showing heightened responsivity in high SPS individuals (Nocentini et al., 2018; Pluess & Boniwell, 2015). However, greater reductions in negative mood outcomes in response to interventions

could be explained by the higher initial baseline levels seen in high SPS individuals. For example, the anti-bullying intervention study found that high SPS boys showed the greatest reduction in victimization and internalising problems, however their levels remained higher than the low SPS boys, even after the intervention (Nocentini et al., 2018). Therefore, measuring reductions in negative affect between high and low SPS groups is not a fair test, as low SPS individuals start with such low levels, there is little scope for further reduction. Another study found that high (relative to low) SPS individuals displayed greater emotional responses to positive film clips (Lionetti et al., 2018). However, on a group level analysis this difference only reached trend level significance ($p = .09$), and there is no indication that this positive mood effect would have persisted after the experiment. Further, low SPS individuals display higher levels of extraversion and lower levels of neuroticism (Lionetti et al., 2018), which suggests that they are likely to experience more inter and intra personal positive experiences, compared to high SPS individuals, and may therefore represent a vantage factor.

Our research suggests that high SPS reflects a risk factor, supporting a diathesis-stress framework. However, as our moderation studies were only cross-sectional we cannot be sure on the direction of effects. Future research should consider longitudinal designs, assessing environmental sensitivity from a life course perspective, starting with early childhood experiences. This is now possible as the measure of SPS has been validated for use in children as young as 8 years (Pluess et al., 2018), and has been used in younger children by using parent report versions (Slagt et al., 2018). Such future research could investigate the development of SPS as a phenotype, i.e., whether it is a stable trait. It would also be better to assess the direction of effects, due to the prospective design, in order to investigate how SPS moderates the environment across development and what the implications of this are.

Research suggests that the impact of negative experiences is greater than the impact of positive experiences, which could explain why we tended to support a diathesis-stress, as opposed to a differential susceptibility model, as effects were stronger in response to negative experiences. This is supported by daily diary studies, which have shown that negative events produce both increased negative affect and decreased positive affect, whereas positive events only produce increased positive affect (David, Green, Martin, & Suls, 1997), and that negative, but not positive events, carry over to influence mood on the following day (Sheldon, Ryan, & Reis, 1996). The ‘bad is stronger than good’ argument, was developed to explain such findings (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). It proposes that a ratio of 5 ‘good’ to every 1 ‘bad’ event should be experienced to maintain adequate levels of mental health. Given this unequal weighting (i.e., that bad experiences have a 5 x greater impact), and that high SPS individuals are thought to be more environmentally sensitive (e.g., a 2 x greater impact), then any negative event will have a much greater impact for a highly sensitive individual ($5 \times 2 = 10$), compared to a low sensitive individual ($5 \times 1 = 5$). For positive events, which have a smaller impact, one could assume that a highly sensitive individual would still show greater responsivity ($1 \times 2 = 2$), compared to a low sensitive individual ($1 \times 1 = 1$), although the discrepancy between the magnitude of influence between positive and negative events would be greater in highly sensitive individuals. Therefore, comparing past positive and past negative experiences, in this thesis, may not have been a fair test of differential susceptibility. Future research could attempt to ameliorate this problem using tightly controlled experimental conditions.

Mechanisms

Little research had previously been conducted on cognitive mechanisms associated with SPS, which could underlie heightened environmental sensitivity. We investigated whether

high SPS was associated with better statistical learning, which could reflect a general mechanism related to environmental sensitivity (*Chapter 5*). We found no evidence that high and low SPS individuals showed differences in statistical learning, measured using a visual contextual cueing task. We had some problems finding the basic contextual cueing effect, despite attempting to create an exact replica of a previously published paradigm, therefore we cannot draw any firm conclusions from this study. Future research should conduct extensive piloting on different versions of the task in order to obtain a reliable contextual cueing effect. However, since conducting this study, we have concluded that high SPS may not reflect heightened environmental sensitivity in a general way, as it only seems to reflect heightened sensitivity to negative experiences. Therefore, our hypothesis that high SPS individuals will show better statistical learning, has weakened. This is partly what led us to conduct the study in *Chapter 6*, as we hypothesised that high SPS individuals would be more likely to show increased learning from particular conditions, such as learning from punishment, which can be regarded as an aversive experience.

Reinforcement learning is as a fundamental behavioural adaptation, yet there may be variation in the degree of learning from reward or punishment seen across individuals. We expected that high SPS individuals would learn particularly better from punishment, due to heightened sensitivity to punishment cues. We tested this using a passive avoidance task, which has shown individual differences across different populations varying in their degree of behavioural inhibition, such as individuals characterised as introverted/extraverted (Nichols & Newman, 1986), psychopathic/non-psychopathic (Newman & Schmitt, 1998), and those carrying the short/long allele of the 5-HTTLPR gene (Finger et al., 2007). We found no differences in error rates amongst either reward or punishment trials, across low, medium, or high SPS groups. This suggests that punishment sensitivity may not be a cognitive mechanism underlying high SPS, as expected. However, there may have been

issues with the task to pick up reliable individual differences, as it was originally developed to assess punishment sensitivity across clinical (psychopathic) individuals, therefore it may not be suitable for use in normal healthy populations. Further, there may be a wider issue related to the *reliability paradox* between experimental and correlational research, which means that reliable experimental effects observed through cognitive behavioural tests are not applicable to individual differences research in normal correlational designs (see later – *Reliability*).

We found an unexpected association between SPS and working memory, as high SPS individuals displayed lower working memory capacity, measured with the Corsi-block tapping task. This may have been related to increased levels of anxiety, which has been consistently associated with high SPS (Liss et al., 2008). Theories of anxiety, such as *Attentional Control Theory*, predict that anxiety impairs working memory, due to increased distractibility from the stimulus-driven attentional system, e.g., heightened attention to threat (M. W. Eysenck et al., 2007). It is assumed that compensatory mechanisms may be used by high anxious individuals, to support performance, which is related to decreased processing efficiency (Derakshan & Eysenck, 2009). The association between high anxiety and low working memory capacity has been supported by a meta-analysis of 177 studies (Moran, 2016). The small correlation we observed between SPS and working memory capacity could then be explained by high levels of anxiety seen in high SPS populations. This could be tested in future research by examining the relationship between SPS and working memory capacity, controlling for levels of anxiety, which we did not measure in our study. Training working memory has been shown to be effective in improving attention control and reducing subjective anxiety (Grol et al., 2018; Sari, Koster, Pourtois, & Derakshan, 2015). Future research could also test whether the effectiveness of working memory training is moderated by SPS, as we might expect that high SPS individuals would show particular improvement.

Our research did not find any learning mechanisms that were associated with SPS, which may have been related to low variability of the behavioural indices measured. Future research may benefit from using EEG in order to directly investigate neural activity, which could provide a better understanding of neural sensitivity related to SPS. For example, assessing Event-Related Potentials (ERP), such as the Feedback-Related Negativity (FRN) deflection, which is a stimulus locked ERP observed around 250ms after task feedback is given. The FRN is sensitive to both positive and negative feedback, particularly when such feedback is unexpected, e.g., receiving worse than expected feedback (Huang & Yu, 2014). The FRN, as well as other ERP's, could be investigated in high and low SPS individuals completing a feedback related task, in order to investigate whether high SPS individuals display greater activity, and under which conditions, e.g., learning from positive or negative feedback, as well as the degree of expectation of such feedback.

Methodological Considerations

Power

Power analysis is a fundamental tool that can be used for planning sample size. Pioneered by Jacob Cohen over fifty years ago (J. Cohen, 1962), it has been used by many researchers since then, although interest in power analysis has increased in recent years, which has been attributed to the replicability crisis in psychology (Perugini, Gallucci, & Costantini, 2018). Based on null-hypothesis significance testing, power refers to the probability of successfully rejecting the null hypothesis when it is false ($1 - \beta$). Power depends on sample size, effect size and the chosen level of significance, and increases when sample size and effect size increase. Power of .80 is considered the conventional level for researchers to aim for (Perugini et al., 2018). Deciding on sample size for the studies in this thesis was largely based on previous research, rather than on power analysis, which could

have limited our ability to detect small effects, such as interactions. For example, post-hoc power analyses on the moderation effects from *Part one* of the thesis, revealed that we were underpowered to detect interaction effects. This is despite the fact that the studies in this thesis used larger sample sizes than previous research. For example, we previously published a study of 188 individuals looking at the interaction between adverse childhood experiences and SPS predicting life satisfaction (Booth et al., 2015). A post-hoc power analysis on this effect (conducted using *G*Power*), looking at the change in R^2 by adding the interaction term ($\Delta R^2 = .02$), revealed that we would have needed 561 participants to achieve power of .80 at the $p < .05$ level, therefore our previous published study was largely underpowered. Therefore, conducting power analyses in the research design phase is a key aim going forward, particularly for testing interactions, which have been estimated to require at least four times greater sample sizes than main effects, due to increased variance associated with interaction terms (Leon & Heo, 2009). Interaction effects may be particularly difficult to find in SPS research, as SPS is a strong predictor of wellbeing outcomes, thus already explains a large proportion of variance, regardless of the influence of environment.

Research from this thesis suggests that SPS interacts with negative experiences predicting heightened responsivity in high SPS individuals (ΔR^2 ranging from .01 to .03), with effect sizes smaller in adolescents compared to adults. Therefore, we recommend testing larger samples (500-1000 individuals) in future research. We found evidence in our adult sample, that SPS also interacts with positive experiences predicting attenuated responsivity in high SPS individuals ($\Delta R^2 = .02$), which was smaller than the interaction with negative experiences ($\Delta R^2 = .03$), therefore even larger sample sizes may be needed to detect interactions with positive environments. However, our research used cross-sectional correlational designs, which are likely to require larger sample sizes compared to more controlled experimental designs. It has been suggested that experimental designs, such as

intervention studies, which randomise participants to a positive or negative condition, have more power, thus require smaller sample sizes (Bakermans-Kranenburg & Van IJzendoorn, 2015). However, such designs may be difficult to implement, for example due to the ethical issues regarding randomising participants to negative conditions, as well as the cost and efficacy involved in designing appropriate interventions. However, this should be a target for future research. For example, including SPS as a potential moderator of treatment efficacy in existing intervention studies, is a promising future direction.

Reliability

Within the individual differences research domain, reliability refers to the extent to which a measure consistently ranks individuals (Hedge et al., 2017). This is important for correlational research, in order to produce replicable effects, as the measure is able to consistently pick up the individuals “true” score (plus some error). Reliability can be assessed with various psychometric indices, such as testing whether a similar score is achieved by the same individual at different time intervals (i.e., test-retest reliability), as well as testing whether different items within a measure appear to assess the same construct (i.e., internal consistency). These indices are widely reported for self-report measures and give a suggestion as to whether a measure is reliable and therefore useful. However, cognitive tasks are not subject to the same psychometric scrutiny, because they have often been developed from the experimental research tradition. In the experimental tradition, a reliable effect is one that nearly always replicates and is shown by most participants in any study (Hedge et al., 2017). For example, the interference effect observed on the Stroop task has recently proven to be highly reliable (Ebersole et al., 2016). Thus, the correlational and experimental traditions are based on different meanings of reliability, which can pose a problem for their compatibility. A reliable experimental effect (e.g., the Stroop) may not be meaningful for

individual differences research, if the effect has too little between-subject variability to produce reliable correlational effects. In fact, many widely used traditional cognitive tasks have recently been shown to produce extremely low test-retest reliabilities, calling into question their applicability for individual differences research (Hedge et al., 2017).

In the current thesis, we attempted to investigate cognitive factors associated with SPS that could support heightened environmental sensitivity. This may have been unfruitful due to the *reliability paradox* explained above. Although to our knowledge no test-retest reliabilities have been reported for the cognitive indices investigated in this thesis, based on the findings of other cognitive tasks, we can assume that they will not have measured reliable constructs based on the meaning of reliability from the individual differences tradition. Future research should aim to investigate cognitive tasks that produce reliable effects for individual differences research, before considering their suitability. This can only be achieved if researchers begin to estimate and consistently report the reliability of cognitive tasks, such as test-retest reliability and internal consistency (e.g., with split-half estimates) (Parsons et al., 2018).

Causality

As we tested cross-sectional models in the current thesis, we cannot be sure on the direction of effects. Although our models were based on theoretical proposals of the direction of effects, future research should aim to conduct more longitudinal research, including the measurement of SPS at multiple time-points. It remains unclear whether SPS moderates the effect of past life experiences on prospective psychological outcomes. It is also unclear whether high SPS is a true risk factor for developing mental health problems, i.e., preceding the onset of disorders, such as anxiety and depression. We aim to assess such longitudinal models in future research with the availability of Wave 3 data from the CogBIAS longitudinal

study. SPS was measured on two occasions in this study, at Wave 2, when participants were on average 14 years old and at Wave 3, when participants were on average 16 years old. This prospective research will be able to use Hierarchical Linear Models to account for the shared variance associated with the repeated measurements, which cannot be accounted for in simple Linear models (Woltman, Feldstain, MacKay, & Rocchi, 2012). This future research will better support the causal structure of our theoretical models of SPS and psychological wellbeing.

Implications & Applicability

Our research suggests that high SPS is a risk factor for developing mental health problems and lack of psychological wellbeing, which is in some part related to heightened sensitivity to negative life experiences. High SPS individuals also display difficulties in emotion regulation, which may mediate these mental health problems. Therefore, implementing strategies designed to improve mental health should be a target for research going forward. High SPS children and adolescents have already shown to be susceptible to improvements in mental health following school-based interventions (Nocentini et al., 2018; Pluess & Boniwell, 2015). This research should be taken further by developing specific training, for example targeting emotion regulation skills, for both child and adult populations experiencing emotional problems. Difficulties in emotion regulation are a central feature of many psychological disorders, therefore developing non-disorder-specific emotion regulation training may be effective in treating disorders, by targeting the mechanism of action (Berking et al., 2008). In a study comparing the efficacy of normal CBT with a version including specific emotion regulation skills training, it was found that the latter was associated with better mental health outcomes, which was mediated by greater gains in the ability to modify negative emotions in particular (Berking et al., 2008). It was concluded that

the ability to modify emotions in a desired direction, or to accept and tolerate negative emotions, is vital for improving mental health. We expect that high SPS individuals would benefit from such training, due to initial low levels of emotion regulation skills, as well as heightened environmental sensitivity. We also found evidence that high SPS individuals may show attenuated responsivity to positive life experiences, therefore training the ability to savour positive emotions may also be helpful, as this ability has also previously been related to improved wellbeing (Quoidbach, Berry, Hansenne, & Mikolajczak, 2010).

Concluding Remarks

Depressive episodes are an extremely common human experience, precipitating from a wide range of environmental triggers, such as daily life hassles, as well as significant traumatic experiences (Lewinsohn et al., 1998). Mental wellbeing, or flourishing, is distinct from simply the absence of depression, but signifies optimal functioning in all aspects of emotional, psychological and social mental health (Keyes, 2002). Positive mental health is an aspiration for many people, however it is harder to achieve for some than others. *Sensory-Processing Sensitivity* (SPS) is a personality trait reflecting increased sensitivity to the environment. We found that those scoring highly on this trait show increased vulnerability for depression and display lower levels of wellbeing, which is related to heightened sensitivity to negative life experiences, such as lack of early caregiver support and adverse life events. While we often can't ameliorate the occurrence of negative life experiences, we can change the way we process such events, which may be beneficial for mental health. High SPS individuals represent a population at-risk for poor mental health, but also represent a population susceptible to change. Tackling the intermediary mechanisms underlying poor mental health may be particularly effective for improving outcomes. Emotion regulation

7. Discussion

difficulties seem to be an important mediating factor, while also being characteristic of high SPS individuals. Therefore, developing better emotion regulation strategies should be a target for future intervention practices, in order to develop skills necessary for resilient functioning following negative life events. More research into the underlying cognitive mechanisms associated with high SPS may also be helpful for developing understanding of individual differences in environmental sensitivity, which could also be used to develop better mental health interventions.

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